Chapter 2

Assessment of Current Conditions

Where to Find the Publication

The Ecological Landscapes of Wisconsin publication is available online, in CD format, and in limited quantities as a hard copy. Individual chapters are available for download in PDF format through the Wisconsin DNR website (http://dnr.wi.gov/, keyword "landscapes"). The introductory chapters (Part 1) and supporting materials (Part 3) should be downloaded along with individual ecological landscape chapters in Part 2 to aid in understanding and using the ecological landscape chapters. In addition to containing the full chapter of each ecological landscape, the website highlights key information such as the ecological landscape at a glance, Species of Greatest Conservation Need, natural community management opportunities, general management opportunities, and ecological landscape and Landtype Association maps (Appendix K of each ecological landscape chapter). These web pages are meant to be dynamic and were designed to work in close association with materials from the Wisconsin Wildlife Action Plan as well as with information on Wisconsin's natural communities from the Wisconsin Natural Heritage Inventory Program.

If you have a need for a CD or paper copy of this book, you may request one from Dreux Watermolen, Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.

Photos (L to R): Kitten tails, photo by Robert H. Read; Karner blue butterfly, photo by Gregor Schuurman, Wisconsin DNR; Red-shouldered Hawk nestlings, photo by Gene Jacobs; cardinal flower, photo by Drew Feldkirchner; Prothonotary Warbler, photo by Mark Musselman, U.S. Fish and Wildlife Service.

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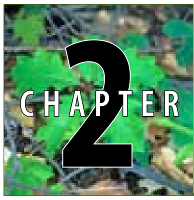


Wisconsin DNR staff

Assessment of Current Conditions

The assessments in this chapter are intended to provide planners and managers with information on the current and past condition of different natural community groups in the state and their importance from a regional and global perspective as well as the best opportunities to manage for them. The statewide community assessments describe (1) the community type; (2) its global/regional importance in Wisconsin; (3) an assessment of the community type today; (4) issues affecting the composition, structure, and function of each community; (5) land use and environmental conditions to consider when planning management; (6) statewide ecological opportunities; (7) ecological opportunities by ecological landscape; and (8) new findings, opportunities, and conservation needs.

This chapter also describes socioeconomic characteristics of the state, which are important to consider when planning natural resource management at large and small ***scales***. The socioeconomic sections describe the history of human settlement and resource use in Wisconsin from the earliest known human occupation until World War II; more recent natural resource characterization and use in the state; and a socioeconomic overview of present-day Wisconsin, including human demography, housing, and important economic sectors.

Statewide Community Assessments

This section provides an assessment of the natural communities found in Wisconsin. Curtis (1959) classified Wisconsin's major forest and grassland communities along a soil moisture gradient into five basic types: wet, wet-mesic, mesic, dry-mesic, and dry communities. Some of the broad types defined by Curtis have been further refined by the Wisconsin Natural Heritage Inventory program, where they are now referred to as natural communities (WDNR 2009). The natural community classification incorporates findings from recently completed vegetation studies and also describes rare or highly localized community types not mentioned by Curtis. These refinements provide a better tool for establishing statewide status and identifying conservation priorities of Wisconsin's natural communities and for exchanging information on current needs across program and administrative boundaries.

The distribution and abundance of Wisconsin's natural communities prior to Euro-American settlement was shaped by numerous natural and human-caused factors. The major factors are discussed in this chapter and in more detail in each of the 16 ecological landscape chapters.

Glaciation has been a major factor on ecosystem development in Wisconsin. Through the ages, most of the state was covered repeatedly by advances of major continental ice sheets. A number of glacial events occurred during the Pleistocene epoch—the most recent was the Wisconsin glaciation. Glaciers reached their maximum southerly extent at about 21,000 years ago and slowly retreated, re-advanced in places, and finally melted back into Upper Michigan. The ice began melting 16,000 years ago, and glaciers were gone from Wisconsin at about 9,500 years ago (WGNHS 2010). Glaciation had dramatic effects on most of the state and strongly influenced which natural communities developed where. For example, unusually high concentrations of lakes formed in the Northern Highland Ecological Landscape; pine forests were able to survive on droughty sands in outwash and lake plain landforms of the northwestern, northeastern, and central parts of the state; and hemlock-hardwood forests formed on the relatively nutrient-rich soils and more mesic conditions associated with morainal landforms. Glacial features are readily apparent throughout much of the state including locations in the southeast with rugged end and ***recessional moraines***, extensive drumlin fields, eskers, ***kames***, ***ice-contact hills***, outwash plains, and lake plains.

The southwestern portion of the state known as the Driftless Area was not covered by the Wisconsin glaciation; it is believed to have been unglaciated for millions of years (Dott and Attig 2004). This landscape is characterized by level or rolling ridges capped with fertile loess soils, deep steep-sided valleys, and frequent outcroppings of Paleozoic sedimentary rock, sandstones, and dolomites.

Following glaciation, windblown silt was deposited over much of Wisconsin. This material, known as loess, was brought

Terms highlighted in green are found in the glossary in Part 3 of the book ("Supporting Materials"). Naming conventions are described in Part 1 in the Introduction to the book. Data used and limitation of the data can be found in Appendix C, "Data Sources Used in the Book," in Part 3.

from the Mississippi River valley by prevailing westerly winds. Areas that received a thick deposit of loess tend to be more mesic because of the moisture-holding capacity of silt. Loess is not deposited evenly over Wisconsin; it drifted and piled up in some places and was later eroded away in others.

In addition to the features left by glaciers, climate, fire, wind disturbance, and other factors contributed to the conditions that occurred across the state prior to Euro-American settlement. For example, fires maintained prairies and savannas in southern Wisconsin and oak and pine barrens in the droughty soils of northwest, northeast, and central Wisconsin. Forests in northern Wisconsin were affected by occasional blowdowns by wind storms.

Knowing the historical natural communities that occupied different regions of the state is somewhat uncertain. Data sets that help to analyze historical land cover are not numerous. The best sources for estimating conditions prior to broadscale Euro-American settlement in Wisconsin are those derived from the federal public land survey information collected in Wisconsin between 1832 and 1866 (Mladenoff et al. 2009). An excellent source that details the methods, use, and limitations of the public land survey data is *The Original U.S. Public Land Survey Records: Their Use and Limitations in Reconstructing Presettlement Vegetation,* by Schulte and Mladenoff (2001), who described the 19th-century survey method as follows:

> Surveyors traversed the boundaries between all sections and, in so doing, marked the intersection of section lines (section corners) and the midpoint between section corners (quarter corners), using a wooden post set into the ground, a mound of earth, or stones. Surveyors also marked the locations where section lines crossed navigable rivers, bayous, or lakes (meander corners). At section, quarter, and meander corners, surveyors "blazed" two to four nearby trees as "witness" or "bearing" trees. Blazing consisted of inscribing the corner identification and coordinates on the tree, so that given locations could subsequently be relocated. Tree species, diameter, compass bearing, and distance from the corner were then recorded in surveyor notebooks. Other data recorded by surveyors, which are frequently used in studies of historical vegetation, include (1) the location of abrupt boundaries between distinct vegetation types (e.g., swamp versus upland forest); (2) incidences of visible fire or wind disturbance; and (3) line and township descriptions of dominant over- and understory species, agricultural suitability of the soils, topography, and Native American and early Euro-American settlements.

The following sections describe seven groups of natural communities known to occur in Wisconsin: grasslands, oak openings and oak savannas, oak and pine barrens, northern forests, southern forests, wetlands, and aquatic communities. The groups follow the community aggregations first presented in the Wisconsin DNR's biodiversity report, *Wisconsin's Biodiversity as a Management Issue* (WDNR 1995), with most groups comprising three or more natural community types. The Ecosystem Management Planning Team updated the material from the biodiversity report in 2001 and again for this publication.

Grassland Communities

Grasslands are characterized by a lack of trees and tall shrubs. In native grasslands the biomass is usually dominated by grasses and/or sedges (*Carex* spp.); however, the species composition may be dominated by forbs. Native grasslands may occur in a continuum of herbaceous communities along environmental gradients such as soil moisture or slope aspect, which eventually grade into oak savanna or forest. Some grasslands include a component of shrubs. The component of native shrubs is desirable, especially in discreet clumps within grasslands (for example, in draws or ravines), where they are necessary habitat features for ***rare*** birds such as Bell's Vireo (*Vireo bellii*) and Loggerhead Shrike (*Lanius ludovicianus*). Over 400 species of native vascular plants are characteristic of Wisconsin prairies, and most are restricted to prairie or savanna community types. In addition to the floristic diversity and variability, grasslands have a diverse and specialized fauna, especially among invertebrates, herptiles, and birds.

Fire was a significant influence on composition, distribution, and dynamics of a large portion of Wisconsin before Euro-American settlement. For example, based on climate, soil moisture, and nutrient levels, many areas in southern Wisconsin were capable of supporting mesic hardwood forests dominated by sugar maple (*Acer saccharum*) and basswood (*Tilia americana*). Fires caused by lightning strikes or started by American Indians, which provided habitat for the game

Floristically rich Wet-mesic Prairie and open-grown bur oak near Eagle in the southern Kettle Moraine. Note prairie dock, tall grasses. Waukesha County. Photo by Drew Feldkirchner, Wisconsin DNR.

they desired and the plants they used, prevented forests from expanding. The ***mosaic*** of oak-dominated forest, savanna, and prairie that covered most southern Wisconsin landscapes into the 1800s was largely the result of fire regimes that existed for 5,000–6,000 years (Bray 1960). Fires were important in other areas, as well, such as the notable barrens communities of the Northwest Sands.

Community Description

The term grassland refers collectively to native plant community types such as prairies and sedge meadows as well as to nonnative habitats such as pastures, hay fields, small grain fields, brome/alfalfa fields, Conservation Reserve Program (CRP) fields, and fields planted for nesting cover. Nonnative grasslands have been referred to as "surrogate grasslands" (Sample and Mossman 1997). Surrogate grasslands meet the needs of some native birds and mammals but provide fewer benefits to native grassland plants and associated invertebrates. Surrogate grasslands include agricultural fields, row crops, fallow fields, old fields, pastures, set-aside (CRP) fields, young conifer plantations, orchards, parks, golf courses, airports, cut-over or burned forest, mossed bogs, and grasslands established on wildlife areas (both cool-season and warm-season grasses) (Sample and Mossman 1997). Therefore, surrogate grasslands benefit some native plants and invertebrates but not the diverse composition and functioning of a native prairie. In the following descriptions of grassland communities, "grasslands" encompass native prairies, sand barrens, fens, bogs, sedge meadows, and bracken grasslands as well as some of the nonnative surrogate grasslands that are important for vertebrate conservation.

Prairies occur on a wide variety of topographies, soil types, and moisture regimes, from saturated peats to excessively drained coarse-textured sands and gravels. Six native types of prairie are recognized on the Wisconsin Natural Heritage Working List (WDNR 2009): sand prairie and the five types identified by Curtis (1959)—wet, wet-mesic, mesic, dry-mesic, and dry. (Wet and wet-mesic prairies are also included in the "Wetland Communities" section of this chapter.)

Sand Barrens are similar to Sand Prairies (and should probably be grouped with them) but show evidence of past agricultural disturbance in the form of sand blows or areas dominated by nonnative weeds.

Calcareous Fens are highly localized wetland communities that support specialized plants of narrow distribution, including many rarities (fens are also included in the "Wetland Communities" section). They develop on saturated peat, which is usually alkaline or neutral, over a source of ***calcium***-enriched groundwater that is close to and may reach the surface.

Curtis (1959) did not address "northern" fens, which do occur in northern Wisconsin. Peaty wetlands north of the ***Tension Zone*** are often referred to as "bogs," but some of these are in direct contact with mineral-enriched groundwater, and such wetlands are now recognized as types of fens.

The dominant forb in late spring on this Wet-mesic Prairie is eastern shooting-star (Dodecatheon meadia). *This prairie occurs on subdued ridge-and-swale topography along Lake Michigan. Chiwaukee Prairie, Kenosha County. Photo by Thomas Meyer, Wisconsin DNR.*

The steep west-facing slope of Battle Bluff supports prairie vegetation with very little woody growth. Vernon County. Photo by Eric Epstein, Wisconsin DNR.

Steep slopes, shallow soils (often with bedrock outcrops), and extreme growing conditions made the Dry (Bluff) Prairies less suitable for conversion to croplands than the highly productive, deep soil tallgrass prairie communities. Battle Bluff, Vernon County. Photo by Eric Epstein, Wisconsin DNR.

Tension Zone

The Tension Zone is an area separating Wisconsin's two major climatic zones (Curtis and McIntosh 1951, Curtis 1959). Along with climate, there is a shift in plant and animal species composition corresponding to this area. Some locations within the Tension Zone contain unusual plant and animal assemblages where a mix of the "southern" and "northern" species occurs. The concept of the Tension Zone is important for understanding the ecology of the state because this area marks the location where natural communities change from prairie, savanna, and mixed hardwood forests of the south to dominance by the mixed deciduous-coniferous forests of the north.

The Bell's Vireo (Wisconsin Threatened) is a rare bird that nests in dense thickets of shrubs within southern Wisconsin's more extensive grasslands. Photo by Steve Maslowski, courtesy of U.S. Fish and Wildlife Service.

True bogs are dominated by sphagnum mosses (*Sphagnum* spp.) and ***ericaceous shrubs*** such as leather-leaf (*Chamaedaphne calyculata*), bog-laurel (*Kalmia polifolia*), and cranberries (*Vaccinium* spp.) and receive nutrients almost entirely from precipitation. Deep deposits of highly acidic peat composed of the remains of sphagnum mosses effectively isolate bogs from contact with mineral-enriched groundwater. The bog flora is composed of relatively few species, but many of the plants and some of the associated animals are highly specialized. (Bogs are also discussed in the "Wetlands Communities" section of this chapter.)

Sedge meadows are treeless wetlands that occur throughout the poorly drained glaciated portions of Wisconsin and, to a more limited extent, within the floodplains and along the borders of rivers and streams in southwestern Wisconsin. The dominant plants are sedges, mixed with grasses and a variety of forbs. (Sedge meadows are also included in the "Wetland Communities" section.)

Bracken Grasslands are restricted to the north where they occur as highly unusual natural or semi-natural openings within otherwise forested uplands. Areas from which trees are entirely absent may receive growing season frosts and are known locally as "frost pockets," which are natural, insular depressions that receive cold air drainage and may suffer killing frosts during any month of the year. The origin of our Bracken Grasslands remains somewhat obscure. Charred stumps were noted in some of northern Wisconsin's Bracken Grasslands (Curtis 1959), and those stands clearly had an association with 19th-century logging. (Bracken Grasslands are also discussed in the "Oak and Pine Barrens Communities" section.)

For more detailed descriptive information on grassland communities, see Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin."

Tussock sedge (Carex stricta) *and Canada blue-joint grass* (Calamagrostis canadensis) *are the dominant graminoid plants in this large Southern Sedge Meadow along the White River in Green Lake County. Photo by Eric Epstein, Wisconsin DNR.*

This series of dry prairies occupies south-facing bedrock bluffs. Wisconsin has exceptional representation of bluff (or "goat") prairies, which are key habitat for numerous native plants, invertebrates, and herptiles. Note the wooded draws between the more exposed bluffs. Morgan Coulee State Natural Area, Pierce County. Photo by Eric Epstein, Wisconsin DNR.

Global/Regional Context

Wisconsin lies on the northeastern boundaries of the North American prairies (Figure 2.1). Most Wisconsin prairies occur within the prairie-forest ecotone and fit into the broad category of tallgrass prairie, which in many areas was intermixed with oak savanna (either Oak Openings or Oak Barrens). Wisconsin's prairies are generally located south and west of the climatic Tension Zone in a roughly triangular area extending from Racine County in Wisconsin's southeastern corner west to Grant County in Wisconsin's southwestern corner and north to Polk County in northwestern Wisconsin. (Figure 2.2).

Tallgrass prairies (which include Wisconsin's Mesic, Dry-mesic, Wet-mesic, and Wet Prairie communities), along with the oak savannas, are among the most decimated and threatened natural communities in the North America and the world. Of the 2.1 million acres of the state's land area (roughly 6%) that were covered by native prairie when Euro-Americans arrived in large numbers 150 years ago (Figure 2.2), only around 2,000 acres (less than one-tenth of one percent) of varying quality native prairie remains today (WDNR 1995). Wisconsin has some of the Upper Midwest's best opportunities for the preservation and restoration of tallgrass prairie compared to tallgrass prairie states such as Iowa and Illinois, where land use has been much more intensive. Soils and topography in Wisconsin have preserved more original prairie sod from cultivation than in these other states, especially in parts of southwestern Wisconsin's Driftless Area and in places such as the southern part of the Kettle Moraine region of southeastern Wisconsin. Most remnant sod is at the dry or wet end of the soil moisture spectrum.

Current Assessment of Grassland Communities

Most native prairies found in Wisconsin today are small remnants. Most of these are less than 10 acres in size, and very few exceed 50 acres, too small to support the full complement of species that would typically inhabit a native prairie ecosystem. Most of the prairies remaining today are either of the wet or, especially, the dry types, in which conversion to agricultural uses was less likely or less effective.

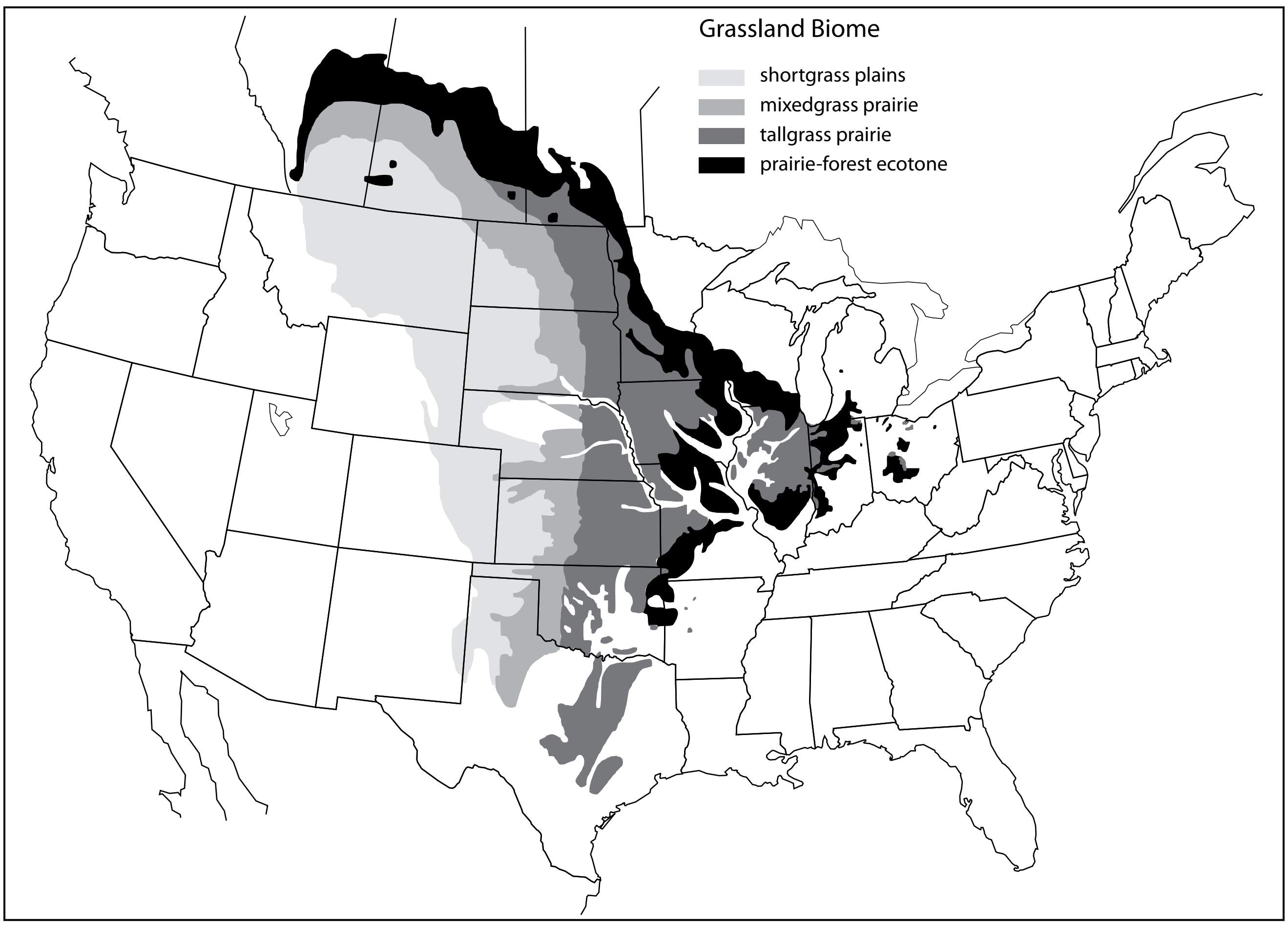


Figure 2.1. *The grassland biome of midwestern North America, showing the general ranges of the tallgrass and mixed grass prairies, shortgrass plains, and prairie-forest ecotone. Depending on local conditions, topographic exposure, moisture-holding capacity of the soil, and other factors, all these midwestern grassland ecosystems may be found in Wisconsin. Reproduced from Cochrane and Iltis (2000; redrawn after Carpenter [1940]).*

The vast majority of Wisconsin's sand prairies have been converted to croplands or pine plantations. This remnant sand prairie supports eastern prickly pear cactus (Opuntia humifusa), *leadplant* (Amorpha canescens), *and many other prairie obligates, including rare animals. Photo by Cathy Bleser, Wisconsin DNR.*

Sullivant's (or "prairie") milkweed (Asclepias sullivanti) *is a Wisconsin Threatened plant strongly associated with undisturbed tallgrass prairie remnants. Photo by Drew Feldkirchner, Wisconsin DNR.*

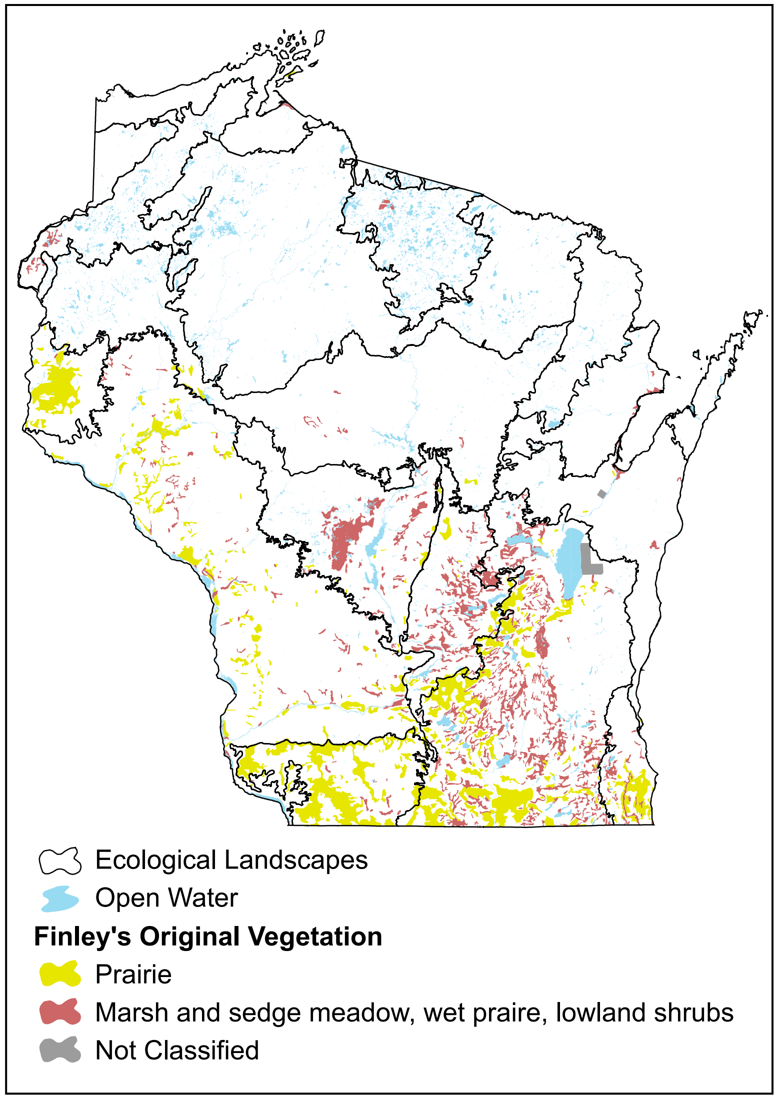


Figure 2.2. *Original prairies, wet meadows, and lowland shrublands. Based on Curtis (1959) and Finley (1976).*

Mesic prairie, which was the most common type prior to Euro-American settlement, is almost gone, with a total of only about 100 acres known to exist today. An estimated 15% to 20% of the state's original grassland flora is now considered rare in Wisconsin (WDNR 1995).

Many rare plants inhabit native prairies. More than 63 plant species of Wisconsin grasslands are now listed as Wisconsin Endangered, Wisconsin Threatened, or Wisconsin Special Concern species (WDNR 1995). Prairie bush-clover (*Lespedeza leptostachya*) is a globally rare prairie plant that was listed as U.S. Threatened in 1987. Among the other rare plant species strongly associated with native prairies are prairie Indian plantain (*Cacalia tuberosa*), wild hyacinth (*Camassia scilloides*), Hill's thistle (*Cirsium hillii*), pale-purple coneflower (*Echinacea pallida*), marbleseed (*Onosmodium molle*), American fever-few (*Parthenium integrifolium*), and prairie turnip (*Pediomelum esculentum*). Glade mallow (*Napaea dioica*), a Wisconsin Special Concern species that inhabits sedge meadows and moist prairies, is a regional endemic occurring only in the north central United States (Cochrane and Iltis 2000).

Most grassland mammal species adapted to the changing conditions that followed Euro-American settlement, but some, such as the American bison (*Bos bison*) and elk (*Cervus elaphus*), were extirpated. Others, such as the prairie vole (*Microtus ochrogaster*) and Franklin's ground squirrel (*Spermophilus franklinii*), became and remain rare.

While some grassland birds, such as Whooping Crane (*Grus americana*) and Long-billed Curlew (*Numenius americanus*), were extirpated relatively quickly after the expansion of Euro-American settlement in the mid-1800s, most grassland bird species did not decline immediately but adapted and shifted to newly created agricultural habitats. But as agriculture has become more intensive over the last 50 years and grassland habitats have been lost to or altered by fragmentation and various developments, grassland bird populations have declined significantly. Currently, the Barn Owl (*Tyto alba*) and Loggerhead Shrike are listed as Wisconsin Endangered; the Greater Prairie-Chicken (*Tympanuchus cupido*), Bell's Vireo, Yellow Rail (*Coturnicops noveboracensis*), and Henslow's Sparrow (*Ammodramus henslowii*) are listed as Wisconsin Threatened; and 12 other grassland bird species are listed as Wisconsin Special Concern (WDNR 2009). The Whooping Crane is currently the focus of a reintroduction effort.

Only about half of reptile and amphibian species associated with prairies (and sedge meadows) have adapted to the loss of native grasslands and still maintain good population levels today. Species such as the ornate box turtle (*Terrapene ornata),* slender glass lizard (*Ophisaurus attenuatus*), and eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) (a candidate for federal listing) are listed as Wisconsin Endangered; Blanding's turtle (*Emydoidea blandingii*) and Butler's gartersnake (*Thamnophis butleri*) are listed as Wisconsin Threatened; and the prairie ring-necked snake (*Diadophis punctatus arnyi*), prairie skink (*Plestiodon septentrionalis*), plains gartersnake (*Thamnophis radix*), North American racer (*Coluber constrictor*), and gophersnake (*Pituophis catenifer*) are listed as Wisconsin Special Concern.

Though there have been recent studies and surveys on the distribution and status of prairie butterflies and moths, leafhoppers, grasshoppers, and spiders, there are still significant gaps in our knowledge of prairie invertebrates. Because some invertebrates depend on specific prairie plants, it is believed that many prairie invertebrates may be extinct, have been extirpated from the state, or are endangered, threatened, or rare today. Prairie invertebrate species new to science are still being discovered in Wisconsin. We will never know which species were lost when most of the native prairies were converted to croplands and pastures or were replaced by various kinds of developments. Among the grassland invertebrates, 19 species are listed as Wisconsin Special Concern, two are Wisconsin Threatened, and five are Wisconsin Endangered.

These nonnative "surrogate grasslands" and scattered oak groves border a stream in southwestern Wisconsin. This site supports many declining grassland birds and some sensitive aquatic species. Photo by Cathy Bleser, Wisconsin DNR.

The Wisconsin Threatened Henslow's Sparrow is a native grassland bird that is now largely dependent on nonnative grassland habitats. Photo by Tom Schultz.

The gophersnake (Wisconsin Special Concern) inhabits dry prairies and barrens. Photo courtesy of U.S. Fish and Wildlife Service.

Issues of Composition, Structure, and Function

Native grassland community composition, structure, and function are dependent on periodic disturbance (primarily fire but also on weather events and patterns such as droughts, grazing, mowing, and other types of disturbance). Other factors of potential importance are location, size, and connectivity between remnants as well as soil type, moisture regime, and slope aspect.

Composition

The predominant composition problem is the absence or decline of grasses, forbs, and associated fauna that are characteristic of native grassland communities. This is especially true for restored prairies, wetlands, and CRP (Conservation Reserve Program) plantings using native plants, which are often dominated by only a few species of prairie grasses and have very low forb cover and diversity. At least two grassland plant species have been extirpated from Wisconsin, and over 63 grassland plant species are listed as Wisconsin Endangered, Wisconsin Threatened, or Wisconsin Special Concern (WDNR 1995).

Grassland birds, in general, are declining dramatically in Wisconsin, throughout the Midwest, and across North America. As a group, grassland birds are among the organisms most in need of management attention. Eighteen species of grassland birds are listed as Wisconsin Endangered, Threatened, or Special Concern (WDNR 2009).

Rare bird species that require large grasslands include the Greater Prairie-Chicken, Short-eared Owl (*Asio flammeus*), Northern Harrier (*Circus cyaneus*), and Upland Sandpiper (*Bartramia longicauda*). The most area-sensitive grassland birds, such as those with lek mating systems, need 10,000 acres or more of continuous open landscape to maintain viable populations. For example, current thinking is that the Greater Prairie Chicken, one of the area-sensitive bird species that uses a lek mating system, may require even larger grassland landscapes to maintain viable populations. Such large-scale landscapes, referred to as Grassland Bird Conservation Areas (Fitzgerald et al. 1998), need to consist of at least 40% to 50% permanent and long-term (≥10 years) grass and forb cover (Sample and Mossman 1997).

Although recent research has provided information on Wisconsin prairie invertebrates (Henderson 2010), much is still unknown about invertebrate species dependent on native prairies. For example, in 1993–94, Wisconsin DNR surveys yielded records for five species new to science and 24 species that were never before recorded in Wisconsin (WDNR 1995). Of the known invertebrates dependent upon habitats such as prairies and fens, many species are extremely rare.

The Wisconsin Endangered regal fritillary (Speyeria idalia)*, a globally rare prairie butterfly, is shown here nectaring on orange milkweed* (Asclepias tuberosa)*. Photo by Ann Swengel.*

The area-sensitive Greater Prairie-Chicken (Wisconsin Threatened) can no longer find sufficient habitat in any of Wisconsin's native grasslands. Its continued existence here is dependent on intensive management of large areas of nonnative grass, mostly in central Wisconsin. Photo by Gerald Bartelt, Wisconsin DNR.

Structure

The predominant structure problem is the replacement of diverse prairie grasses and forbs of varying height and density with monotypic agricultural crops or exotic cool-season grasses and encroachment by trees and shrubs. Patch size, configuration, and isolation are important horizontal components of grassland habitats. Grassland birds and some other animals have specific structural requirements involving variable vegetation height and density. Grasslands should be managed to provide both vertical and horizontal structural habitat variability that accommodates grassland fauna, especially for those species that are sensitive and declining.

Function

The predominant function problem for many native grasslands is the lack of periodic fire. Other important functional factors include competition, especially with invasive plants; succession, leading to tree and shrub encroachment; and reduction, fragmentation, and isolation of remnant patches. Among other problems, isolation and fragmentation make it difficult, or even impossible, for species that are lost from a grassland remnant to recolonize it. For nonnative (surrogate) grasslands the predominant function problems are haying or grazing disturbances that are too intensive or done at the wrong time of the year to avoid negative impacts to sensitive species, insufficient disturbance to prevent the encroachment of woody vegetation, and the various negative impacts associated with increased housing development. These issues may also affect composition or structure.

Land Use and Environmental Considerations

Major grassland issues that should be considered when planning management are the small size and isolation of remaining prairie remnants, the lack of fire to create the necessary disturbance to maintain them, the invasion and competition from invasive species, conflicting management programs (planting trees in native prairie or in designated grassland areas), increasing rural development, lack of incentives to maintain native prairies, and the high cost of restoring native prairie. These issues, along with the fact that only 0.1% of native prairies are left in the state, make the management and preservation of native grasslands and their associated biota a high priority.

The following list describes the major threats to Wisconsin's grasslands:

- Most prairie remnants are too small, isolated, and degraded (e.g., from lack of fire, overgrazing, invasion by exotics) to ensure long-term viability of all characteristic native plant and animal populations.
- Almost all of the former native prairies (especially mesic sites) are now used for agricultural production. Native prairies persist mostly on small sites that are too dry, too wet, too rocky, or too steep for farming.

Prescribed burn in progress to maintain and expand good quality Dry Prairie on a Driftless Area bluff in the Western Coulees and Ridges Ecological Landscape. Photo by Armund Bartz, Wisconsin DNR.

- Many prairie sites were grazed excessively, reducing the number of prairie plants that exist on the remnants and allowing nonnative plants adapted to such uses to flourish.
- The introduction and spread of invasive species has degraded and eliminated some existing native prairies and made it more difficult and expensive to restore and manage native prairie.
- There are few incentive programs that are designed to help private landowners protect or maintain existing prairie remnants with the exception of the Landowner Incentive Program (LIP; see bullet under the "New Findings, Opportunities, and Conservation Needs" section below). ***Use tax*** rates may encourage the grazing of prairies, which most often is incompatible with maintaining the native flora.
- Rural residential development is increasing and fragmenting Wisconsin's agricultural (open) landscapes with houses, golf courses, infrastructure, and associated trees and shrubs. These residential developments can destroy, fragment, and impair the function of prairie remnants and other grasslands.
- Lack of cooperation among and within agencies has encouraged tree planting on existing grasslands including native prairies and in areas that were historically prairie regions of the state.
- The Conservation Reserve Program (CRP) has provided thousands of acres of grassland including some native plantings that can provide short-term cover (10 years) for grassland wildlife along with some economic gain for landowners. In recent years, CRP enrollment has declined because of higher prices for agricultural crops (see the "New Findings, Opportunities, and Conservation Needs" section below).

Fire was the key disturbance factor that promoted and maintained native prairies in Wisconsin. Below are some issues relating to the use of fire to maintain grasslands in Wisconsin.

- Lack of fire on many prairie remnants is allowing trees, shrubs, and nonnative grasses to replace native prairie plants.
- Historically, the message that "all fire is bad" has created a cultural fear of fire that often hinders the use of prescribed burning needed to maintain and restore native prairie.
- Education is needed to inform the public of the necessity of fire for preserving prairies, even on prairies in areas of high human density (e.g., Chiwaukee Prairie in Kenosha County or the University of Wisconsin-Madison Arboretum prairies).
- Adequate ***refugia*** from annual fire for fire-sensitive invertebrates are needed on sites with those species present.

- Increasing residential developments and air quality standards could reduce the use of prescribed burning as a management tool for maintaining native prairie.

Since most native prairies have been lost in Wisconsin, restoration of this community type is needed, but it is difficult and expensive. The following are some issues impacting the restoration of grasslands in Wisconsin:

- The high cost of restoring native prairies can be an obstacle to the restoration of large areas of prairie as can the needed investments in time and effort.
- Limited availability of local genotype seed was a factor that hindered the restoration of large areas of native prairie. Prairie seed farms producing local genotype seeds have made this less problematic in recent years (see "New Findings, Opportunities, and Conservation Needs" below).
- The high cost of productive agricultural and recreational land makes it difficult for conservation organizations to buy and restore native prairie, especially the rarest tallgrass types such as mesic prairie, which typically occurred on sites that are now prime farmland. The same is true for private landowners who may wish to restore native prairie but also need an economic return from the land. This underscores one of the major obstacles in directing the attention of conservationists where it is needed most.

Statewide Ecological Opportunities for Grassland Communities

Wisconsin has many opportunities to preserve prairie remnants and restore grassland communities. However, restoration will be a difficult and costly job because many of the native prairie plants and seed sources have been lost after decades of intensive agricultural use, heavy grazing, increases in the abundance of invasive species, and lack of burning. Most opportunities for restoring grasslands occur in southern and western Wisconsin in the former prairie region south of the Tension Zone, although there are some grassland management opportunities for surrogate grasslands (such as CRP and other nonnative permanent grasslands) on former agricultural lands north of the Tension Zone. Sedge meadows and fens in the north also support native grassland species.

To ensure that the full range of species composition is preserved, grasslands should be restored across the entire former range of the prairies. All prairie types (wet to dry), soil types, and important environmental gradients should be represented. This will undoubtedly be easier to accomplish for some types than for others, given competing land uses and values. To improve the context and increase the effective conservation area and viability of small isolated prairie remnants, some former agricultural land will likely need to be restored to prairie or managed in a way that is compatible with maintaining or restoring the native prairie biota. Where needed and feasible, grassland corridors should be created to further enhance the movements of native plants and animals. Removal of trees along fence lines and woody patches within grassland areas would increase grassland connectivity and effective habitat size.

Grassland restoration is possible for most, but not all, ecosystem components. Restoration of a vast functional grassland ecosystem that can accommodate wide-ranging megafauna such as American bison, elk, and gray wolves (*Canis lupus*) is neither practical nor feasible in the heavily developed and highly populated landscapes of southern Wisconsin today. However, restoration of smaller sites composed mostly of native vegetation and management of large-scale landscapes that include both native and surrogate grasslands as well as some agricultural lands may make it possible to accommodate most of the flora and fauna of grassland ecosystems.

Two strategies for maintaining grassland communities in Wisconsin should be considered. One is to restore larger grassland landscapes that include native prairies but may

Large-scale prairie, meadow, fen, and savanna restoration and management is occurring on state-owned lands within the Scuppernong River Basin, Waukesha County. Photo by Eric Epstein, Wisconsin DNR.

This restoration project along the Upper Branch of the Pecatonica River will restore grasslands, wetlands, ponds, and meanders along a prairie stream. Photo by Cathy Bleser, Wisconsin DNR.

also include surrogate grasslands (CRP and other nonnative relatively permanent grasslands) and agricultural lands. The other is to preserve and protect remnant native prairies with sufficient ***buffers*** around them to ensure their viability. These approaches are not mutually exclusive, and in fact both will be needed to restore and maintain the full spectrum of composition, structure, and functions characteristic of grassland ecosystems. For more details on the number and size of grasslands needed, see Henderson and Krause (1995), Henderson and Sample (1995), and Sample and Mossman (1997).

Small remnant sites have the potential, at least in the short- and mid-term, to support many native grassland plants, soil microfauna and microflora, and invertebrates if they're located in open landscapes that support populations of these grassland species. Buffering these small remnants with other grassland habitat should allow for the expansion of remnant vegetation through management and seed dispersal. Large sites will be needed to support many of the vertebrates such as mammals, birds, and herptiles that require larger grasslands and open landscapes. These landscapes can be a mix of native and surrogate grasslands. However, small native prairie sites should not be ignored or considered "covered" within large grassland projects. These small native prairie sites may contain important elements of a functioning prairie ecosystem (e.g., soil microflora and microfauna, local genotype seed, and invertebrates) that could be lost if not given management attention. These components of a functioning prairie cannot be easily replicated in prairie restorations. Corridors connecting grassland sites along latitudinal gradients should be considered and planned in the near future.

Henderson and Sample (1995) recommended establishment of both upland and lowland sites primarily in former grassland landscapes and in some areas of the state that were not formerly prairie but where large grassland landscapes currently exist. Specifically, they recommended the following:

- Four to five large-scale grassland landscapes (>10,000 acres) that include native prairie, surrogate grasslands, and agriculture may be needed to accommodate the requirements of some bird species.
- Ten to twelve medium-scale grassland landscapes (1,000–5,000 acres) that include native prairie, surrogate grasslands, and agriculture may be needed to accommodate vertebrates and some invertebrates across the range of former prairies.
- Numerous scattered grassland sites of native or surrogate grasslands of at least 40 acres in size (80 to 250 acres and larger are preferred) may need to be restored throughout the prairie region of the state to protect and maintain the full spectrum of native plants and animals associated with native prairie habitats.
- Numerous native prairie remnants of any size may need to be preserved and managed to maintain the genetic

Extensive grasslands still occur in a few parts of southwestern Wisconsin. These sites are composed of CRP lands, pasture, hayfields, and small native prairie remnants and provide critical habitat for many prairie species. Photo by Eric Epstein, Wisconsin DNR.

This partially restored Sand Prairie and Oak Barrens complex is situated on a broad terrace along the Mississippi River. Trempealeau National Wildlife Refuge, Trempealeau County. Photo by Eric Epstein, Wisconsin DNR.

This open landscape in southwestern Wisconsin is composed of CRP lands, grassy pastures, hayfields, and remnant prairies. Such areas are now very scarce, but they provide essential habitat for Wisconsin's grassland fauna. Photo by Thomas Meyer, Wisconsin DNR.

diversity of native species across the prairie region of the state. These remnants may provide a "blueprint" and local genotype seed source for larger restorations and are refugia for prairie-dependent soil microorganisms and invertebrates.

Sample and Mossman (1997) identified twenty-six priority landscapes and other sites for grassland restoration and management (Figure 2.3). These landscapes encompass the different prairie types and include both large and small-scale restoration opportunities. Sample and Mossman's top priority landscapes for grassland restoration and management south of the Tension Zone are as follows:

- Thompson Prairie Grasslands (now part of the Wisconsin DNR's Southwest Wisconsin Grassland and Stream Conservation Area; Iowa, Lafayette, Dane, and Green counties)
- Muralt/Monroe Grasslands (Green County)
- Buena Vista/Leola Grasslands (part of the Wisconsin DNR's Central Wisconsin Grassland Conservation Area; Portage and Adams counties)
- White River Marsh Complex (Marquette and Green Lake counties)
- Star Prairie Pothole Grasslands (currently a Wisconsin DNR project called the Western Prairie Habitat Restoration Area; St. Croix and Polk counties)
- Yellowstone/Pecatonica River Grasslands and Savannas (now part of the Wisconsin DNR's Southwest Wisconsin Grassland and Stream Conservation Area; Lafayette and Iowa counties)
- Fort McCoy Barrens (Monroe County)
- Lower Wisconsin River prairies and barrens (Iowa, Sauk, Grant, Dane, and Richland counties)

For more detailed descriptions of these priority grassland restoration areas, see Sample and Mossman (1997) and Henderson and Krause (1995). The Wisconsin Natural Heritage Inventory identifies the locations of high quality native prairie remnants and sites where rare species on the Wisconsin Natural Heritage Working List have been documented (WDNR 2009). However, more inventory work is needed to identify additional remnants that may be of lesser quality but which may have value as restoration sites, as buffers, or as sources of seeds representing local genotypes.

Ecological Opportunities by Ecological Landscape

The best opportunities for preserving, enhancing, and restoring grassland communities can be found in the following ecological landscapes:

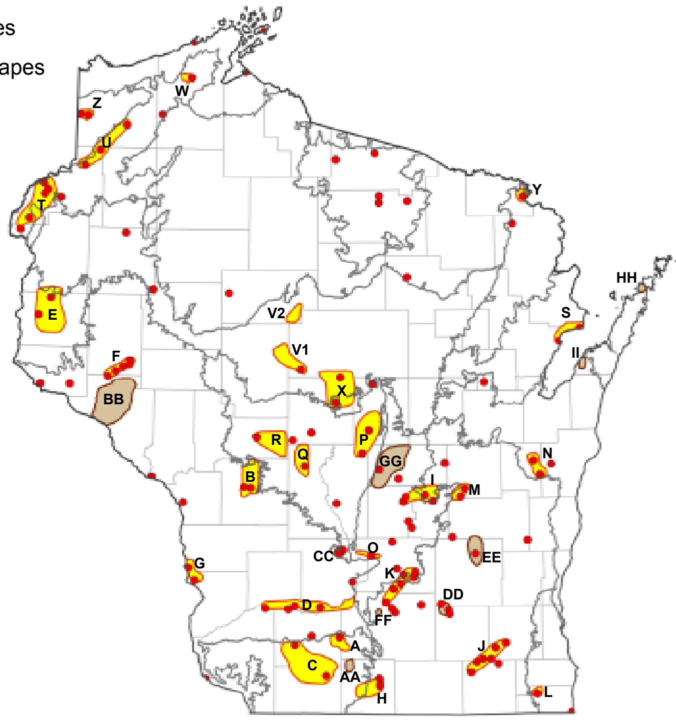
- Southwest Savanna
- Western Coulees and Ridges
- Western Prairie
- Central Sand Plains
- Southeast Glacial Plains
- Forest Transition

New Findings, Opportunities, and Conservation Needs

This section discusses the most recent research results, programs, and challenges regarding grasslands that should be considered when planning grassland management in Wisconsin.

- In late 2009, the Wisconsin Natural Resources Board approved the implementation of the Southwest Wisconsin Grassland and Stream Conservation Area, a large grassland, savanna, and stream conservation project in the Southwest Savanna Ecological Landscape of southwestern Wisconsin.
- Prairie, wetland, and savanna restoration in the Scuppernong River ***Basin*** in the Southern Unit of the Kettle Moraine State Forest (Jefferson and Waukesha counties) has increased the area of open landscape from small, scattered, isolated remnants to over 3,500 acres. This restoration work has also led to the discovery of numerous populations of rare plants and animals.
- A research project to inventory sensitive prairie invertebrates in southern Wisconsin was done under the direction of plant ecologist Rich Henderson. This survey inventoried 190 prairie remnants in Wisconsin and, along with work done in neighboring states, indicated that there may be as many as 2,000 species of insects restricted to remnant prairie sod with native prairie plants in the Upper Midwest. Most of these are, or were, native to Wisconsin prairies. Because their habitat is now so limited, most of these prairie-restricted insects likely deserve listing as Species of Greatest Conservation Need. The Wisconsin survey found dozens of species never before documented in the state and several species not yet named in the scientific literature. Even very small prairie remnants (less than 1/4 acre in size) isolated for over 130 years, still harbored highly specialized and rare prairie-restricted insects.
- The Wisconsin DNR has a number of grassland protection efforts underway including the Glacial Habitat Restoration Area, the Western Prairie Habitat Restoration Area, and the Central Wisconsin Grassland Conservation Area. The Glacial Habitat Restoration Area project has restored 22,400 acres of grassland and 6,400 acres of wetlands across an 800-square-mile area. These are surrogate grasslands that benefit many nesting grassland birds such as Eastern Meadowlark (*Sturnella magna*), Bobolink

Ecological Landscapes
County Boundaries
Primary Landscapes
Secondary Landscapes



Location	Priority Landscapes
	Southwest Savanna Ecological Landscape
A	Thomson Prairie Grasslands
C	Yellowstone/Pecatonica River Grasslands and Savannas
	Western Coulees and Ridges Ecological Landscape
B	Fort McCoy Barrens
F	Lower Chippewa River Savannas and Prairies
G	Rush Creek/Battle Bluff Goat Prairies and Savannas
D	Lower Wisconsin River Prairies and Barrens
	Southeast Glacial Plains Ecological Landscape
H	Muralt/Monroe Grasslands
I	White River Marsh Complex
J	Southern Kettle Moraine Complex
K	Columbia/Dane County Prairie Wetlands
M	Rush Lake Grasslands and Sedge Meadows
O	Pine Island Area Grasslands
	Southern Lake Michigan Coastal Ecological Landscape
L	Bong Recreation Area
	Central Lake Michigan Coastal Ecological Landscape
N	Brillion/Killsnake Grasslands
	Central Sand Plains Ecological Landscape
P	Buena Vista/Leola Grasslands
Q	Necedah Barrens
R	Bear Bluff Wetlands
	Northern Lake Michigan Coastal Ecological Landscape
S	Green Bay West Shore Sedge Meadows
	Northwest Sands Ecological Landscape
T	Crex Meadows/Fish Lake Complex
U	Namekagon/Douglas County Barrens
W	Moquah Barrens
	Northeast Sands Ecological Landscape
Y	Spread Eagle Barrens
	Forest Transition Ecological Landscape
V (1,2)	North Central Prairie Chicken Grasslands
X	Mead/Paul J. Olson Grasslands
	Northwest Lowlands Ecological Landscape
Z	Black Lake/Belden Swamp
	Western Prairie
E	*Star Prairie Pothole Grasslands*

Location	Secondary Landscapes
	Southwest Savanna Ecological Landscape
AA	York Prairie Grasslands
	Western Coulees and Ridges Ecological Landscape
BB	Buffalo River/Lima Mounds Savannas
CC	Mirror Lake Barrens
	Southeast Glacial Plains Ecological Landscape
DD	Waterloo Area Prairies
EE	Horicon Marsh Grasslands
FF	St. Peter's Prairie
	Central Sand Hills Ecological Landscape
GG	Coloma Barrens and Savannas
	Northern Lake Michigan Coastal Ecological Landscape
HH	Liberty Grove Grasslands
II	Brussels Area Grasslands

Figure 2.3. *Location of priority and secondary landscapes and sites for grassland bird management in Wisconsin (from Sample and Mossman 1997). See Sample and Mossman (1997) for priority ranking within natural division.*

(*Dolichonyx oryzivorus*), Henslow's Sparrow, Grasshopper Sparrow (*Ammodramus savannarum*), and Savannah Sparrow (*Passerculus sandwichensis*) in addition to ducks and pheasants.

- The identification of prairie remnants by knowledgeable field biologists remains a critical need for agency and nongovernmental organization (NGO) partners engaged in grassland conservation.
- Local land trusts and NGOs such as The Prairie Enthusiasts and The Nature Conservancy have been actively protecting, restoring, and managing prairies in southern Wisconsin.
- Streambank protection efforts (e.g., Conservation Reserve Enhancement Program and grassland buffer strips along streams) have had benefits not only for aquatic systems and the organisms that inhabit them but also for the grassland landscapes through which they flow. This has been especially important and appropriate in southwestern Wisconsin. However, care needs to be taken so that grassland buffers for streams are used in grassland landscapes and not in areas managed for forest.
- Since 2006 the Wisconsin DNR's Landowner Incentive Program (LIP) has funded projects focused on the regions that historically supported extensive prairie and

savanna vegetation. These projects assist private landowners and support their efforts to protect, restore, and manage rare grassland and savanna habitats and associated species on their lands.

- Invasive species, especially the exotic spurges (*Euphorbia esula* and *E. cyparissias*), wild parsnip (*Pastinaca sativa*), and spotted knapweed (*Centaurea biebersteinii*), are increasingly problematic in some areas. A number of invasive woody plants have become equally problematic, especially the Eurasian buckthorns (*Rhamnus cathartica* and *R. frangula*) and honeysuckles (especially *Lonicera tatarica* and the hybrid *Lonicera* x *bella* but also *L. mackii and L. morrowii*).
- The degree to which fire can be safely used as a management tool on sites inhabited by sensitive invertebrates remains controversial and unresolved. More research on this topic is needed, with adequate control sites to ensure protection of at risk populations of rare species.
- The acreage of lands enrolled in the Conservation Reserve Program has declined in recent years (Figure 2.4) because higher financial returns have been available for alternative land uses (e.g., growing corn for ethanol production) and because landowners have had difficulties meeting some of the stringent (and increasingly expensive) requirements of the program.

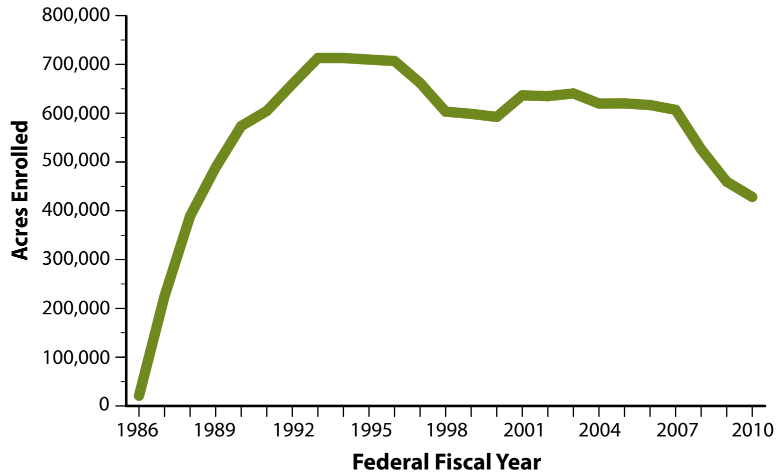


Figure 2.4. *Acres enrolled in the Conservation Reserve Program in Wisconsin, 1986–2010.*

- The Wisconsin Natural Heritage Inventory should be expanded to encompass surrogate grasslands or at least areas of surrogate grassland concentration. It will be impractical to include all or even most individual locations of surrogate grasslands within the Natural Heritage Inventory (which tracks a record or series of records of rare, endangered, threatened, and special concern plant and animal species, and natural communities at a specific geographic location), but some means of tracking areas that provide essential grassland habitat at large scales is needed.
- The Wisconsin DNR's prairie seed farm is up and running and can provide native prairie seed appropriate for various Wisconsin locations and other types of technical assistance to managers engaged in grassland restoration projects. (For information about the prairie seed farm, contact the ***State Natural Areas*** program in the Wisconsin DNR's Bureau of Endangered Resources.)

Scientific names of species mentioned in the grassland communities assessment.

Common name	Scientific name
American basswood	*Tilia americana*
American bison	*Bos bison*
American fever-few	*Parthenium integrifolium*
Barn Owl[a]	*Tyto alba*
Bell's Vireo	*Vireo bellii*
Blanding's turtle	*Emydoidea blandingii*
Bobolink	*Dolichonyx oryzivorus*
Bog-laurel	*Kalmia polifolia*
Butler's gartersnake	*Thamnophis butleri*
Canada blue-joint grass	*Calamagrostis canadensis*
Cranberries	*Vaccinium* spp.
Cypress spurge	*Euphorbia cyparissias*
Eastern massasauga rattlesnake	*Sistrurus catenatus catenatus*
Eastern Meadowlark	*Sturnella magna*
Eastern prickly pear cactus	*Opuntia humifusa*
Eastern shooting-star	*Dodecatheon meadia*
Elk	*Cervus elaphus*
Eurasian buckthorns	*Rhamnus cathartica* and *R. frangula*
Eurasian honeysuckles	*Lonicera tatarica, Lonicera* x *bella, L. mackii, L. morrowii*
Franklin's ground squirrel	*Spermophilus franklinii*
Glade mallow	*Napaea dioica*
Gophersnake	*Pituophis catenifer*
Grasshopper Sparrow	*Ammodramus savannarum*
Gray wolf	*Canis lupus*
Greater Prairie-chicken	*Tympanuchus cupido*
Henslow's Sparrow	*Ammodramus henslowii*
Hill's thistle	*Cirsium hillii*
Leadplant	*Amorpha canescens*
Leafy spurge	*Euphorbia esula*
Leather-leaf	*Chamaedaphne calyculata*
Loggerhead Shrike	*Lanius ludovicianus*
Long-billed Curlew	*Numenius americanus*
Marbleseed	*Onosmodium molle*
North American racer	*Coluber constrictor*
Northern Harrier	*Circus cyaneus*
Orange milkweed	*Asclepias tuberosa*
Ornate box turtle	*Terrapene ornata*
Pale-purple coneflower	*Echinacea pallida*
Plains gartersnake	*Thamnophis radix*
Prairie bush-clover	*Lespedeza leptostachya*
Prairie Indian plantain	*Cacalia tuberosa*
Prairie ring-necked snake	*Diadophis punctatus arnyi*
Prairie skink	*Plestiodon septentrionalis*
Prairie turnip	*Pediomelum esculentum*
Prairie vole	*Microtus ochrogaster*
Regal fritillary	*Speyeria idalia*
Savannah Sparrow	*Passerculus sandwichensis*
Sedges	*Carex* spp.
Short-eared Owl	*Asio flammeus*
Slender glass lizard	*Ophisaurus attenuatus*
Sphagnum mosses	*Sphagnum* spp.
Spotted knapweed	*Centaurea biebersteinii*
Sugar maple	*Acer saccharum*
Sullivant's (prairie) milkweed	*Asclepias sullivanti*
Tussock sedge	*Carex stricta*
Upland Sandpiper	*Bartramia longicauda*
Whooping Crane	*Grus americana*
Wild hyacinth	*Camassia scilloides*
Wild parsnip	*Pastinaca sativa*
Yellow Rail	*Coturnicops noveboracensis*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologists Union.

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Oak Savanna Communities: Oak Openings

Community Description

Oak savannas are plant communities that were defined arbitrarily by John Curtis in *The Vegetation of Wisconsin* (1959) as having no less than one tree per acre and no more than a 50% tree canopy. This represents a broad continuum of plant community structures from nearly treeless open prairies to forests. Curtis further subdivided Wisconsin savannas into four major categories: oak opening, cedar glade, oak barrens, and pine barrens. Oak openings (and cedar glades) are the subject of this section; the last two communities are discussed in the "Oak and Pine Barrens Communities" section of this chapter.

Oak openings were described by Curtis (1959) as savannas on relatively rich dry-mesic to mesic soils with a partial canopy composed mostly of bur oak (*Quercus macrocarpa*) or white oak (*Q. alba*). An oak savanna variant, not described by Curtis, occurs on wetter soils (wet-mesic) and is dominated by bur and, especially, swamp white oak (*Q. bicolor*). Cedar glades were defined by Curtis as savannas on dry limestone bluffs, with eastern red-cedar (*Juniperus virginiana*) more prevalent than oaks. Today, many ecologists in and around Wisconsin do not consider the cedar glade as a distinct natural community. They are generally regarded as dry prairies or oak openings that have been heavily invaded by eastern red-cedar due to past grazing and the exclusion of periodic fire. Most of the following information relates to oak openings.

Historically, oak openings were common south of the Tension Zone (Figure 2.5), where they often occurred on mesic to dry-mesic sites (and more rarely on wet-mesic sites) with relatively high nutrient availability. They also occurred on more **xeric** sites with thin or stony soils. The vegetation was characterized by scattered large oaks with distinctive limb architecture interspersed with varying assemblages of grasses, forbs, and brush. Oak openings were thought to have had less grass and more forb and shrub cover than prairie but more grass and fewer forbs than closed canopy forest. The dominant tree species are bur oak and white oak although black oak (*Quercus velutina*), shagbark hickory (*Carya ovata*), big-tooth aspen (*Populus grandidentata*), and black cherry (*Prunus serotina*) may also be present. The oaks

The Oak Woodland community occupied an ecotone between more open savannas (in this case, Oak Openings) and closed canopy forests. Frequent fires of low intensity were thought to have maintained the open conditions and filtered light needed by the native understory species. Note the limb structure. Kettle Moraine State Forest – South Unit, Jefferson County. Photo by Drew Feldkirchner, Wisconsin DNR.

The open aspect of this Oak Opening had been maintained by many decades of livestock grazing. Relatively few native understory plants are thriving at this time, but the site is now undergoing restoration that includes prescribed burning, mechanical brushing, limited herbicide use, and a reduction in grazing pressure. Note the size, spacing, and limb architecture of the open-grown oaks. Waukesha County. Photo by Eric Epstein, Wisconsin DNR.

Following cessation of grazing, this remnant Oak Opening quickly filled in with aggressive nonnative shrubs, including honeysuckles, buckthorns, multiflora rose, and Japanese barberry. This site is now being managed with prescribed fire and mechanical brush removal by the Holtz family. Waukesha County. Photo by Eric Epstein, Wisconsin DNR.

are generally widely spaced and open-grown (although small, relatively dense groves may occur in draws or on other sites in which fire did not carry well), with large lower branches that sometimes sweep close to the ground. Open-grown bur and white oaks characteristically have large, low, relatively horizontal branches on all sides of the trunk, indicating that sunlight was available on all sides throughout most of the tree's development. This contrasts with the limb structure of forest-grown oaks in which the orientation of the branches is more vertical and more of them occur toward the top of the tree where they compete for sunlight in the forest canopy. The groundlayer dominants are forbs and grasses and sometimes include native shrubs, which differ from those species associated with true forest (a savanna is not simply a forest that has been temporarily opened up via a disturbance of some sort). Oak openings are dynamic but relatively stable communities in the presence of fire (especially frequent fires of low intensity). On most sites, in the absence of fire the canopies close in, shrubs and saplings increase, light levels are diminished, and the ground layer gradually becomes more forest-like.

Rare oak opening plants include purple milkweed (*Asclepias purpurascens*), wild hyacinth, kitten tails (*Besseya bullii*), cream gentian (*Gentiana alba*), slender bush-clover (*Lespedeza virginica*), woolly milkweed (*Asclepias lanuginosa*), eared false foxglove (*Tomanthera auriculata*), roundstem foxglove (*Agalinis gattingeri*), violet bush-clover (*Lespedeza violacea*), yellow evening primrose (*Calylophus serrulatus*), upland boneset (*Eupatorium sessilifolium* var. *brittonianum*), hoary tick-trefoil (*Desmodium canescens*), and yellow giant hyssop (*Agastache nepetoides*). Because so few sizable remnants of this community are extant, the animal life is not well understood. Rare animals associated with oak openings include slender glass lizard and Red-headed Woodpecker (*Melanerpes erythrocephalus*).

Kitten tails (Wisconsin Threatened) is a rare but characteristic herb of Wisconsin's oak savannas. It is more abundant in southern Wisconsin, especially in the Kettle Moraine region, than anywhere else in the world. Photo by Robert H. Read.

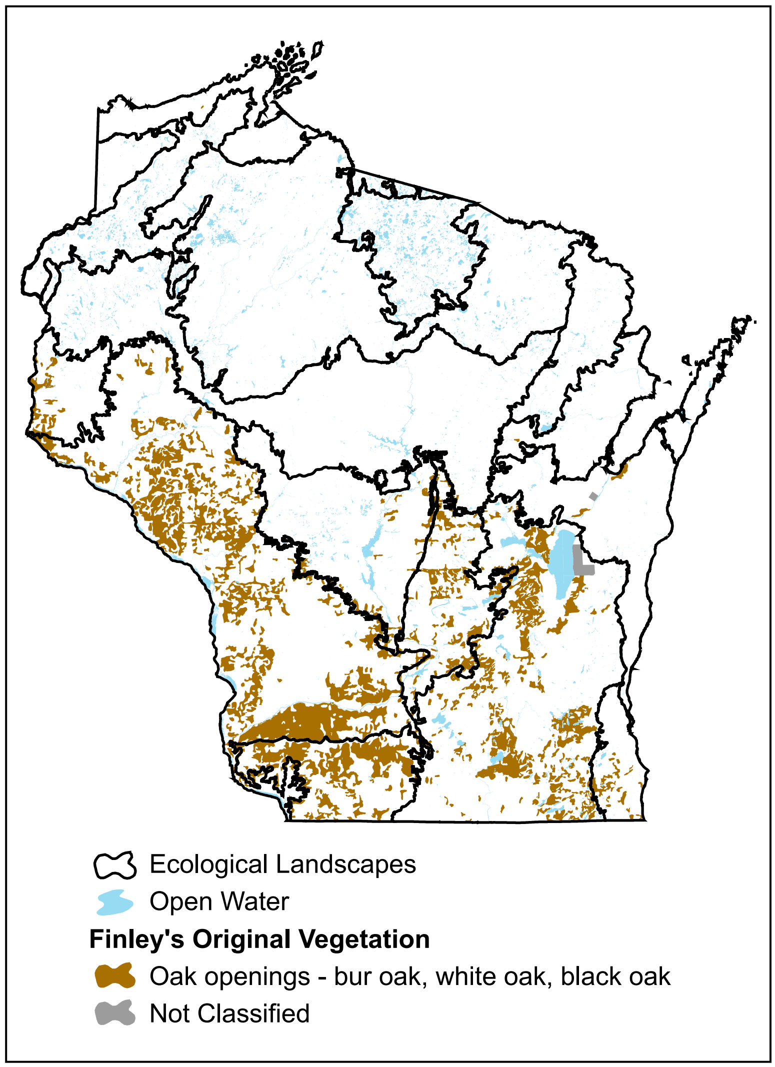

Figure 2.5. *Original oak openings. Based on Curtis (1959) and Finley (1976).*

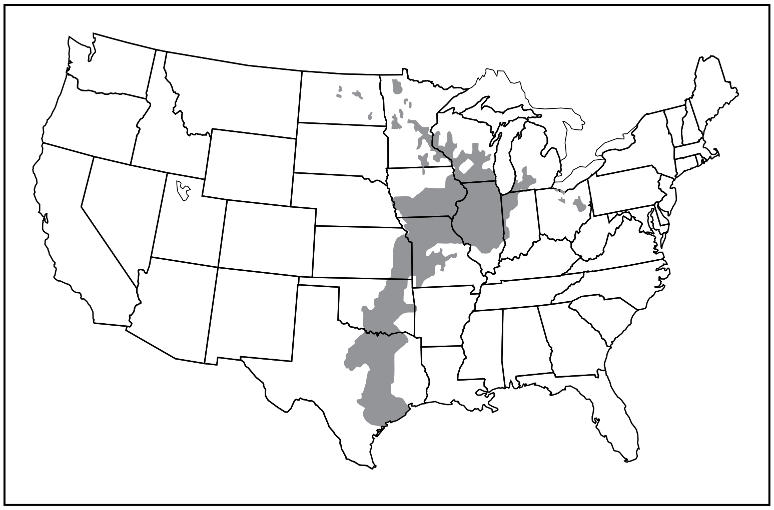

Figure 2.6. *The distribution of midwestern oak savannas and woodlands prior to Euro-American settlement. Based on Nuzzo (1986). This figure was reproduced with permission of the Natural Areas Association from an article published in the Natural Areas Journal 6(2):6–36 by V. A. Nuzzo in 1986.*

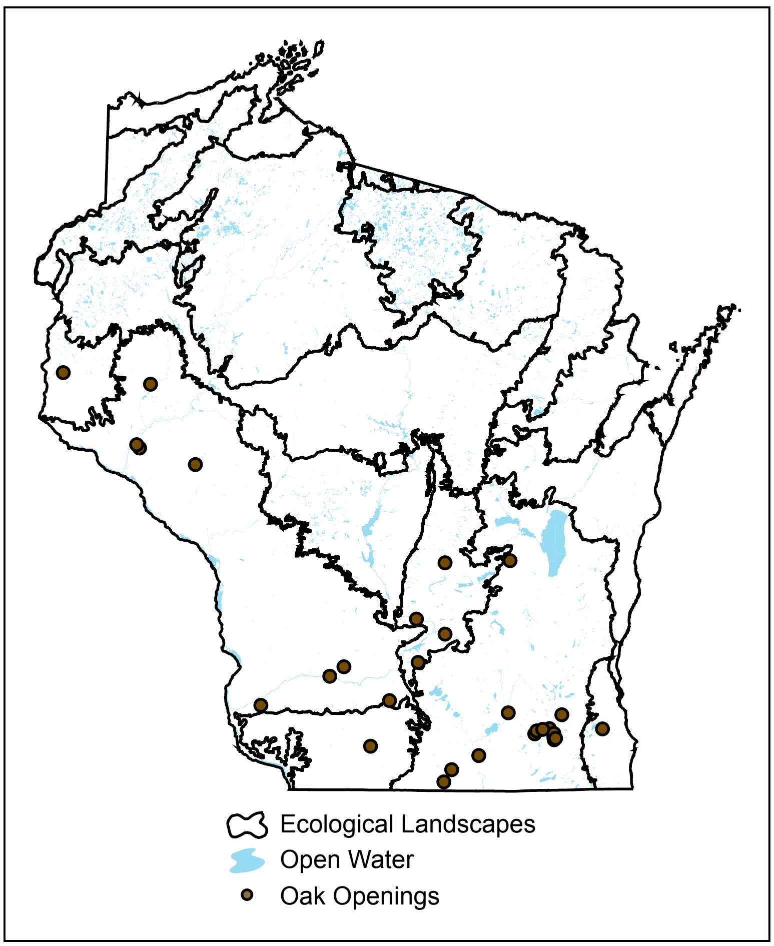

Figure 2.7. *Oak opening occurrences in Wisconsin, 2009 (WDNR 2009).*

Global/Regional Context

In North America, oak openings existed primarily in the Midwest, including Minnesota, Wisconsin, Iowa, Illinois, Michigan, Indiana, Ohio, Missouri, Arkansas, Oklahoma, and Texas (Figure 2.6). Within this broad geographic range there were several distinct plant associations.

Wisconsin's Oak Openings community (Figure 2.7) is endemic to The Nature Conservancy's "Prairie-Forest Border Ecoregion." NatureServe classifies this plant community as "North-central Bur Oak Opening," which has been given the global conservation status rank of G1 (critically imperiled) as of 2010 and is found only in parts of Wisconsin, Minnesota, Iowa, and Illinois. Oak Openings are imperiled globally because of their extreme rarity and the small size, poor condition, and context of most remnants. This is one of the most threatened major plant communities in North America. Wisconsin has some of North America's best opportunities to restore and maintain this community type, especially in the relatively rugged terrain of the Driftless Area and the southern part of the Kettle Moraine region, where agricultural activities and other developments have been somewhat less intensive than in many other parts of the Upper Midwest.

Oak openings occurred in Wisconsin in the prairie-forest floristic province (Curtis and McIntosh 1951, Curtis 1959) south and west of the Tension Zone. Curtis (1959) and Finley (1976) estimated that oak openings covered approximately 5.5 million acres in the southern half of Wisconsin in the mid-1800s (16% of the state) and made up 75% of the total oak savanna community type. Conservation of all savanna communities will be dependent on active restoration and management.

Current Assessment of the Oak Opening Community

Less than 1,000 acres of relatively intact Oak Openings are known to persist today, scattered at roughly two dozen sites. Few, if any, of these occurrences are viable unless there is a significant commitment to intensive restoration activities at a scale that will support all or most of the associated species. Protected sites containing Oak Openings are typically small and isolated (Figure 2.7). Most remnants occur on dry, rocky, gravelly, and/or hilly sites, but a continuum of soil types, slope, aspect, and other site factors needs representation, including mesic and wet-mesic sites.

Additional information on the current composition of oak savannas may be found in Packard (1993) and Pruka (1995). See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," for a more detailed description of the Oak Opening community.

Issues of Composition, Structure, and Function

Oak Opening composition, structure, and function are dependent on fire disturbance, location, size, and connectivity as well as use and management history (such as the intensity and frequency of past grazing by domestic livestock or the use of prescribed fire).

Composition

The predominant composition problem is the lack of characteristic savanna groundlayer species and the invasion of nonnative shrubs and herbs.

- Most Oak Openings have succeeded to southern forest communities because of fire exclusion, have lost their characteristic groundlayer species due to grazing or shading, have been converted to suburban or rural residential areas, have been overrun by invasive plants, or have been converted to agricultural use, including pastures.
- Many plant species that are savanna specialists are now uncommon and found primarily on the fringes of or in openings within oak forests. This can give the false impression that populations of such species are "secure," as they are associated with habitats that have been disturbed in some way. Most remaining savanna remnants are too small and isolated to ensure long-term viability of all of their characteristic native plants and animals. However, at the present time, these remnants may support species that are found at only a few other locations. Recolonization of remnants by native flora and fauna once they have been lost can be difficult, if not impossible, because of this isolation. The intervening ***cover types*** and habitats are often unsuitable for or even hostile to the dispersal of the native organisms between stands.
- Many stands have been colonized by invasive exotic plants such as Eurasian honeysuckles (especially *Lonicera tatarica* and the hybrid *Lonicera* x *bella* but also *L. mackii and L. morrowii*) and buckthorns, multiflora rose (*Rosa multiflora*), Japanese barberry (*Berberis thunbergii*), garlic mustard (*Alliaria petiolata*), smooth brome grass (*Bromus inermis*), and reed canary grass (*Phalaris arundinacea*). The ground layers of stands with a long history of heavy grazing are usually dominated by nonnative cool-season grasses. See Czarapata (2005) for details on each of these invasive plants, their Wisconsin distributions and habitat affinities, and control methods.
- Certain native plants, especially those tolerant of relatively high levels of shade or of heavy grazing can also be problematic in oak savannas. Examples include common prickly-ash (*Zanthoxylum americanum*), red maple (*Acer rubrum*), and cherries (*Prunus* spp.).

Large open-grown bur oaks and tallgrass prairie remnant between Genesee and North Prairie, Waukesha County. Photo by Eric Epstein, Wisconsin DNR.

The understory of this remnant oak savanna is choked with shrubs and saplings, many of them aggressive nonnative species. Near Pell Lake, Walworth County. Photo by Eric Epstein, Wisconsin DNR.

Structure

The predominant problem with the structure of Oak Openings is the absence of fire, resulting in an increase in tree and shrub density and higher levels of shade. This creates conditions unsuitable for the more light-demanding savanna flora.

- Many currently or formerly grazed Oak Openings have the character of an "old tree museum" in which only large old trees are present, and there is little or no evident reproduction of oaks or hickories. Native understory plants are poorly represented in most heavily grazed stands.
- Small sites established to protect savannas are vulnerable to excessive damage from wind and winter storms and various negative edge effects, especially where the remnant savanna is now bordered by cropland or residential areas, rather than prairie or forest.

Function

The predominant problem affecting function of oak savannas is the lack of fire. Habitat fragmentation, stand isolation, and the spread and increase of invasive species are also key factors affecting long-term viability of Oak Openings.

- Many stands appear to be in a "static" condition, although in fact they are slowly losing many of their important compositional and structural components.
- There is little information or research available on minimum viable habitat size for species strongly associated with savannas or on the potential importance of ***ecological context*** at large scales.

Land Use and Environmental Considerations

Several factors should be considered when planning management for Oak Openings. Lack of fire, rural home development, and, until recently, the lack of incentives for landowners to maintain or restore Oak Openings are problems with restoring and maintaining this community type. The Landowner Incentive Program does provide support to private landowners with opportunities to restore savanna communities.

- Because of the aesthetic appeal of Oak Openings, they are prime targets for suburban and rural home development.
- There are too few economic incentives for private landowners to preserve or manage Oak Openings per se, despite their state and global rarity.
- The need for and use of prescribed burns to maintain Oak Openings is often poorly understood by local citizens, who may raise concerns over safety, aesthetics, and air quality. Managers and conservationists, especially in formerly rural but rapidly urbanizing areas, will need to engage in effective educational efforts to address these concerns and fears.
- Use of rotational cattle grazing may be an additional tool in restoring or maintaining the vegetation structure needed by many savanna species, especially for birds and mammals (see the "New Findings, Opportunities, and Conservation Needs" section below).
- In appropriate locations, State Wildlife Management Areas could be managed to increase socially important wildlife species by restoring, maintaining, and expanding oak openings, which can provide excellent habitat for game species such as Wild Turkey (*Meleagris gallopavo*), white-tailed deer (*Odocoileus virginianus*), and eastern gray and eastern fox squirrels (*Sciurus carolinensis and S.*

Historically, savannas and associated thickets provided important habitat for the Northern Bobwhite, now a Wisconsin Special Concern species. Photo by Jack Bartholmai.

This prescribed burn in the Driftless Area is designed to reduce the abundance of woody understory vegetation and promote the growth of native savanna and prairie plants. Photo by Armund Bartz, Wisconsin DNR.

The Blanding's turtle (listed as Wisconsin Threatened) inhabits a variety of open wetland communities and adjoining uplands, including barrens and oak openings. Photo by Gregor Schuurman, Wisconsin DNR.

niger). Brushy edges and thickets of shrubs and saplings provide good habitat for eastern cottontail rabbits (*Sylvilagus floridanus*) and Northern Bobwhite (*Colinus virginianus*). Historically, elk, Greater Prairie-Chicken, and the now-extinct Passenger Pigeon (*Ectopistes migratorius*) used oak openings. Oak brush is an important component of Sharp-tailed Grouse (*Tympanuchus phasianellus*) habitat, and there may be a few sites large enough, where maintaining brush would be appropriate, to support this area-sensitive species (see the section on "Oak and Pine Barrens" for more information on management opportunities for Sharp-tailed Grouse).

Statewide Ecological Opportunities for Oak Savanna Communities

There are substantial opportunities in southern Wisconsin for the restoration of Oak Openings, but this may require more than just reinstating a burning and/or cutting regime to maintain open understory conditions. Some groundlayer species may need to be reintroduced, and invasive plants will need to be controlled or eliminated. Virtually all restoration and management opportunities exist south and west of the Tension Zone. To restore and preserve variations in oak savanna composition and structure and to conserve the full suite of associated species, sites selected for restoration should occur across the original range of this community type and represent major environmental gradients such as soil type, slope aspect, and patch size.

All high-quality remnants (i.e., those with relatively high savanna species richness and community integrity) and mildly degraded sites with high recovery potential merit consideration for management. Both small and large sites should be inventoried and protected. Ideally, the best sites would be large and adjoin either extensive forests or grasslands or both. Small, high-quality sites should not be ignored, for they may be the last refuge for many savanna plants, insects, and soil microflora and microfauna. Where the opportunities exist, restoration efforts should be concentrated in areas where they can expand or connect existing remnants and recreate more natural ecotones between grasslands and forest.

Two different approaches may be needed for Oak Opening restoration. Remnants in which Oak Opening structure is present but where characteristic groundlayer plants are missing (this is often the case in pastured Oak Openings) will need to have appropriate grasses, forbs, and shrubs reintroduced. It is also likely that on stands in this condition, management actions to promote the reproduction of oaks (of the appropriate species and at the appropriate densities) will be needed. In oak savanna remnants that have been grazed over long periods of time, only a single cohort (occasionally multiple cohorts) of very old, large trees may be present.

In remnant Oak Openings where native savanna understory plants are present but in low numbers (e.g., in overgrown oak woodlots), tree and shrub density will need to be reduced through the use of periodic prescribed fire and/or mechanical removal. Some invasive plants are best controlled through the judicious use of herbicides because cutting or burning may stimulate sprouting.

Wisconsin offers some of the best restoration opportunities for Oak Openings on the North American continent, primarily because of the less intensive land uses that have occurred in the Driftless Area (large portions of the Western Coulees and Ridges and Southwest Savanna Ecological Landscapes) and in the southern part of the Kettle Moraine region of the Southeast Glacial Plains Ecological Landscape. The best-known opportunities to preserve/restore the Oak Opening community at relatively large scales include the Southern Unit of the Kettle Moraine State Forest (Jefferson, Waukesha and Walworth counties), Pecatonica and Yellowstone River

Remnant Oak Opening, within an outstanding natural features complex of Wet-mesic Prairie, Southern Sedge Meadow, Emergent Marsh, and Shrub-carr. Puchyan Prairie State Natural Area, Green Lake County. Photo by Eric Epstein, Wisconsin DNR.

Opportunities to restore and manage savanna and grassland habitats at large scales such as this are now rare in the Upper Midwest. Driftless Area landscape, Lafayette County. Photo by Cathy Bleser, Wisconsin DNR.

valleys (Iowa and Lafayette counties), Pleasant Valley Pastures (Dane County), Buffalo River Bluffs (Buffalo County), and Lima Mound (Pepin County) (Henderson and Krause 1995). The Lower Wisconsin State Riverway, lower Chippewa River (Buffalo, Dunn, and Pepin counties), Mukwonago River Watershed (Waukesha and Walworth counties), Rush Creek Bluffs (Crawford County), and Gasner Hollow Prairie State Natural Area (Grant County) offer excellent restoration and management opportunities at moderate to large scales, along with opportunities to manage for adjacent forest, grassland, and wetland communities. Small-scale management opportunities occur elsewhere in southern Wisconsin, especially in the Western Coulees and Ridges and Southeast Glacial Plains ecological landscapes.

Ecological Opportunities by Ecological Landscape

The best opportunities for preservation, enhancement, and restoration of Oak Opening communities can be found in the following ecological landscapes:

- Southeast Glacial Plains
- Western Coulees and Ridges
- Southwest Savanna
- Central Sand Hills
- Western Prairie
- Central Sand Plains
- Southern Lake Michigan Coastal

New Findings, Opportunities, and Conservation Needs

- The Wisconsin Natural Resources Board approved the Southwest Wisconsin Grassland and Stream Conservation Area in late 2009. This major grassland, savanna, and stream conservation project in southwestern Wisconsin will go a long way toward filling a high priority conservation need.
- Restoration of oak openings is the management focus of several major projects, including Rush Creek State Natural Area, Gasner Hollow Prairie State Natural Area, the Southern Unit of the Kettle Moraine State Forest, and the Mukwonago River Watershed.
- Oak savannas are dynamic communities with variable structure, especially in the tree canopy. The proximity of open grasslands to woodlands and forests in which canopy closure is comparatively high requires careful consideration when planning conservation activities, especially on large, publicly owned sites that may offer more management flexibility than smaller, more isolated sites or on sites with multiple private ownerships where coordination and cooperation can be difficult.
- A Wisconsin study used Scottish Highland cattle to test the effectiveness of managed grazing as a tool for restoring the structure of overgrown savannas in Lafayette county (Harrington and Kathol 2009). The authors of the study concluded that managed grazing can be a tool to reduce shrubs in degraded savanna systems.
- Restorable examples of Oak Openings (and Oak Barrens and Pine Barrens) should be identified, assessed, and archived within a database such as the Natural Heritage Inventory. Criteria need to be developed on how to define, evaluate, and prioritize restoration opportunities to enable conservation planners to improve decision making. Effective conservation of rare and dynamic communities such as these will be almost entirely dependent on restoration activities.
- Wisconsin's Landowner Incentive Program (LIP) has been providing funds to private landowners since 2006 to assist them in their efforts to manage and restore remnant savannas and grasslands on their properties. Promising savanna restoration projects are now underway at locations in the Southeast Glacial Plains, Southwest Savanna, and Western Coulees and Ridges Ecological Landscapes.

Scientific names of species mentioned in the oak savanna communities assessment.

Common name	Scientific name
Big-tooth aspen	*Populus grandidentata*
Black cherry	*Prunus serotina*
Black oak	*Quercus velutina*
Bur oak	*Quercus macrocarpa*
Blanding's turtle	*Emydoidea blandingii*
Cherries	*Prunus* spp.
Common prickly-ash	*Zanthoxylum americanum*
Cream gentian	*Gentiana alba*
Eared false foxglove	*Tomanthera auriculata*
Eastern cottontail rabbit	*Sylvilagus floridanus*
Eastern fox squirrel	*Sciurus niger*
Eastern gray squirrel	*Sciurus carolinensis*
Eastern red-cedar	*Juniperus virginiana*
Elk	*Cervus elaphus*
Eurasian buckthorns	*Rhamnus cathartica* and *R. frangula*
Eurasian honeysuckles	*Lonicera tatarica, Lonicera* x *bella, L. mackii, L. morrowii*
Garlic mustard	*Alliaria petiolata*
Greater Prairie-chicken[a]	*Tympanuchus cupido*
Hoary tick-trefoil	*Desmodium canescens*
Japanese barberry	*Berberis thunbergii*
Kitten tails	*Besseya bullii*
Multiflora rose	*Rosa multiflora*
Northern Bobwhite	*Colinus virginianus*
Passenger Pigeon	*Ectopistes migratorius*
Purple milkweed	*Asclepias purpurascens*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Red maple	*Acer rubrum*
Reed canary grass	*Phalaris arundinacea*
Roundstem foxglove	*Agalinis gattingeri*
Shagbark hickory	*Carya ovata*
Sharp-tailed Grouse	*Tympanuchus phasianellus*
Slender bush-clover	*Lespedeza virginica*
Slender glass lizard	*Ophisaurus attenuatus*
Smooth brome grass	*Bromus inermis*
Swamp white oak	*Quercus bicolor*
Upland boneset	*Eupatorium sessilifolium* var. *brittonianum*
Violet bush-clover	*Lespedeza violacea*
White oak	*Quercus alba*
White-tailed deer	*Odocoileus virginianus*
Wild hyacinth	*Camassia scilloides*
Wild Turkey	*Meleagris gallopavo*
Woolly milkweed	*Asclepias lanuginosa*
Yellow evening primrose	*Calylophus serrulatus*
Yellow giant hyssop	*Agastache nepetoides*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologist Union.

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Oak and Pine Barrens Communities

Community Description

Curtis (1959) grouped oak barrens and pine barrens with several other communities under the broader heading of "savannas." The barrens plant communities occur on infertile, coarse-textured, droughty soils and are dominated by grasses, forbs, low shrubs, and scattered trees. Consistent elements of all barrens communities include the presence of a tree component (of highly variable composition, stature, and density) and dependence on periodic fire for maintenance over time. The prairie flora tends to be well represented in oak barrens and pine barrens, especially in stands near and to the south and west of the Tension Zone. Bracken Grasslands in northeastern and north central Wisconsin and barrens on Great Lakes sandspits may demonstrate a greatly reduced prairie component, or it may be entirely absent.

Historically, the most extensive barrens were in large areas of level or rolling sandy glacial outwash or in the sandy beds of extinct glacial lakes, but they also occurred on river terraces, old dune systems associated with drained glacial lakes, gravely moraines, and sandspits. Geographically, the concentration of barrens vegetation was greatest in northeastern, northwestern, and central Wisconsin (Figure 2.8). These areas correspond well to the Northwest Sands, Northeast Sands, and Central Sand Plains ecological landscapes. Barrens, including some that were dominated by jack pine (*Pinus banksiana*), were also common on broad sandy terraces along the Mississippi, lower Wisconsin, lower Chippewa, and lower Black rivers, all in the Western Coulees and Ridges Ecological Landscape. Remnant barrens still occur on some of these sand terraces, but stands in which conifers of natural origin are the prevalent trees are now relatively scarce.

Pine barrens distribution was centered on areas of extensive sandy soils, mostly to the north and east of the Tension Zone. They also occurred in the Central Sand Plains Ecological Landscape and at a few locations in southwestern Wisconsin's Western Coulees and Ridges Ecological Landscape. Jack pine was the most common tree, but red pine (*Pinus resinosa*) may have been present, albeit usually in reduced abundance. Hill's oak (also known as northern pin oak) (*Quercus ellipsoidalis*) and bur oak may have occurred in a reduced state as ***oak grubs***, no more than a few feet tall, or as a scattering of larger trees. The understory was composed of grasses, sedges, and forbs, many of them associated with sand prairies. Low shrubs of the heath family, such as blueberries (*Vaccinium* spp.) and bearberry (*Arctostaphylos uva-ursi*) and more robust shrubs, such as prairie willow (*Salix humilis*), prairie red-root (*Ceanothus herbaceus*), New Jersey tea (*C. americanus*), and hazelnuts (*Corylus americana* and *C. cornuta*), were often prominent members of the northern barrens flora.

Oak barrens were savannas in which black oak or Hill's oak were the most common trees. Jack pine was absent or in low abundance, and the understory consisted mostly of plants associated with sandy prairies. The oak barrens community occurred primarily south and west of the Tension Zone.

In some parts of Wisconsin, barrens vegetation does not fall neatly into the "oak barrens" or "pine barrens" categories. Mixed stands (with both pine and oak present) are known from areas in northwestern, central, and southwestern Wisconsin (they're "mixed" for a variety of reasons, including manipulation by humans). The Michigan Natural Features Inventory has recently published a description of a mixed "oak-pine barrens" community (Kost et al. 2007).

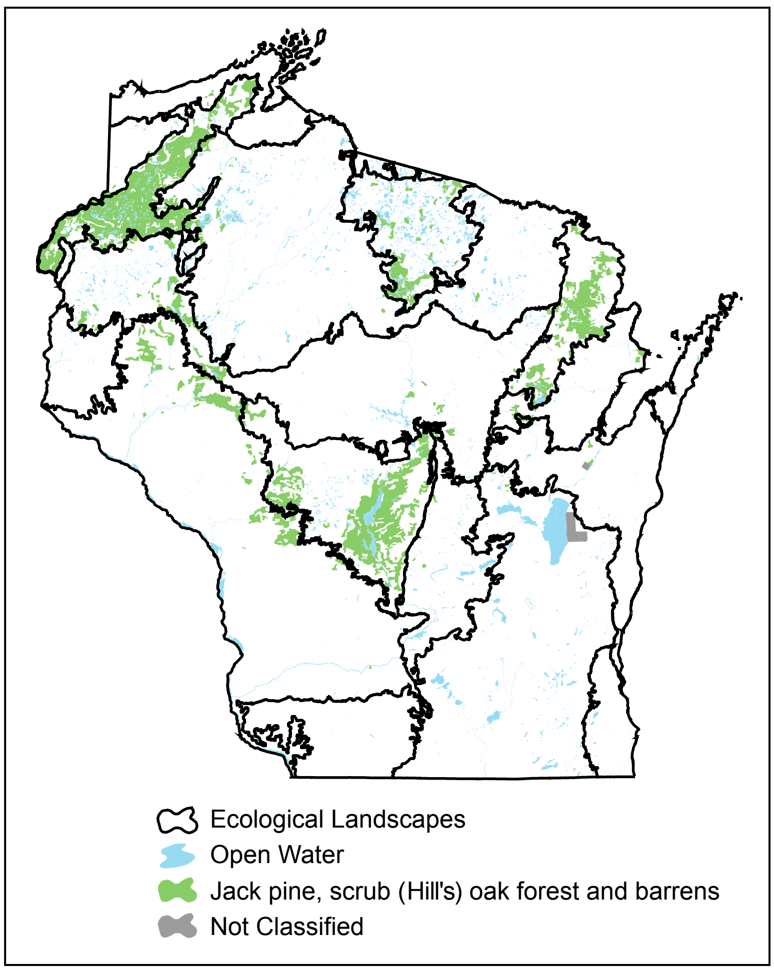

Figure 2.8. *Original oak and pine barrens. Based on Curtis (1959) and Finley (1976).*

In addition, events that followed Euro-American settlement, such as logging, grazing, and extended periods of fire suppression, altered the structure and composition of virtually all stands. Many partially restored stands dominated by pines in the mid-1800s are now dominated entirely by oaks. The use of prescribed fire to restore and manage the coniferous tree component of pine-dominated barrens ecosystems has proven to be challenging.

The treeless "sand barrens" community described by Curtis (1959) has been somewhat modified and changed to Sand Prairie, which is discussed in the "Grassland Communities" section of this chapter.

Great Lakes Barrens and Bracken Grasslands are rare communities that constitute less than 5% of the remaining barrens acreage. The extremely rare Great Lakes Barrens community has been documented only in association with sandspits on Lake Superior and Lake Michigan. On Lake Superior the tree component may consist of widely spaced red pines (pine savannas) or dense but scattered stands of jack pine. The prairie flora is absent from the Lake Superior occurrences, and the understory is made up mostly of low shrubs such as junipers (Juniperus spp.), serviceberries (Amelanchier spp.), cherries, blueberries, false heather (Hudsonia tomentosa), and herbs characteristic of bare sand habitats. Soil development is minimal owing to the dynamic nature of sandspit environments on open Great Lakes coastlines. Highly specialized lichens, mosses, and fungi are present.

This Pine Barrens community features a sparse canopy of large pines, thickets of deciduous brush, and herb-dominated openings composed mostly of native prairie species. Glacial outwash sands, southern Douglas County. Photo by Eric Epstein, Wisconsin DNR.

Great Lakes Barrens. Scattered open-grown red pines are interspersed with openings composed of native grasses and shrubs such as common juniper (Juniperus communis)*, false heather, and blueberry. This fine example of an extremely rare community occurs on a sandspit (a double **tombolo**) in Lake Superior's Apostle Islands. Ashland County. Photo by Eric Epstein, Wisconsin DNR.*

Bracken Grasslands are natural or semi-natural open areas found mostly in north central and northeastern Wisconsin. Existing stands often occur in depressions where growing season frosts may limit the growth of trees. The vegetation is characterized by low shrubs, such as blueberries and sweet-fern (*Comptonia peregrina*), along with bracken fern (*Pteridium aquilinum*), grasses, sedges, and other herbs. Bracken Grasslands are sometimes treated as barrens, but the prairie flora is reduced and may be entirely absent. Non-native weedy species are often common, and colonization of these sites by trees may be extremely slow (if it occurs at all). The origins of these northern openings remain obscure. At some sites the combined impacts of past logging, subsequent severe slash fires that destroyed or diminished the organic material in the soil, and frost action have produced treeless vegetation. The ***allelopathic*** properties of several of the common herbs, including bracken fern and the exotic orange hawkweed (*Hieracium aurantiacum*), may also play a role in keeping some of these sites relatively free of trees (Curtis 1959). (Bracken Grasslands are also discussed in the "Grassland Communities" section.)

All barrens are a tenuous group of communities pulled in opposing directions by periodic disturbances, especially fire, and succession. Depending on the severity and frequency of disturbance, the barrens community can vary structurally from open lands dominated by grasses, shrubs, and suppressed trees, to savanna-like areas featuring a scattering of trees or groves, to dense closed canopy forests. The following sections describe attributes and issues related to the more open barrens.

Among the numerous rare barrens-associated species are the U.S. Endangered Karner blue butterfly (*Lycaeides melissa samuelis*) and Kirtland's Warbler (*Setophaga kirtlandii,* listed as *Dendroica kirtlandii* on the Wisconsin Natural Heritage Working List; WDNR 2009) and the Wisconsin Endangered and federal "candidate" species the eastern massasauga rattlesnake. Many other rare species are dependent on or strongly associated with barrens, including birds, reptiles, insects, and plants. Among the examples are Sharp-tailed Grouse, slender glass lizard, Blanding's turtle, northern blue butterfly (*Lycaeides idas*), frosted elfin butterfly (*Incisalia irus*), phlox moth (*Schinia indiana*), sand violet (*Viola fimbriatula*), rough white lettuce (*Prenanthes aspera*), woolly milkweed, brittle prickly pear (*Opuntia fragilis*), ternate grape fern (*Botrychium rugulosum*), and prairie fameflower (*Talinum rugospermum*). Some of the common wildlife species associated with barrens habitats have important recreational values, including the white-tailed deer, black bear (*Ursus americanus*), and Wild Turkey. The Sharp-tailed Grouse, a game bird of great interest to a small but devoted group of hunters, has become increasingly rare in Wisconsin and now persists primarily at a few intensively managed sites, mostly in the Northwest Sands Ecological Landscape.

Global/Regional Context

Wisconsin has one of the most significant opportunities in North America—quite possibly the best opportunity—to preserve, restore, and manage barrens communities, especially at larger scales. Both of Wisconsin's major barrens communities are considered globally rare by NatureServe (Faber-Langendoen 2001) due to the relatively low number of occurrences, restricted distributions, generally poor condition, and vulnerability to further loss. Pine Barrens has a global conservation status rank of G2 (imperiled), and Oak Barrens has a global conservation status rank of G3 (vulnerable).

The Pine Barrens community is rare, geographically restricted, and globally imperiled. In North America, Pine Barrens exist primarily in the Upper Midwest, especially in Wisconsin, Michigan, and Minnesota. The community with similar vegetation often referred to as "pine barrens" in the northeastern United States (e.g., in New Jersey) is also globally rare but composed of an almost entirely different assemblage of species (and completely lacking the prominent prairie component found in Wisconsin barrens) and is structurally, and possibly functionally, different than the midwestern types.

Oak Barrens is a rare and globally imperiled community. Significant opportunities for Oak Barrens protection and restoration exist in Wisconsin, but with few exceptions, most of these are at a relatively small scale of few hundred acres or less. Conversion of barrens to agricultural uses has been more common in southern Wisconsin (the primary geographic range of Oak Barrens) than in the north. Conversion of barrens to monotypic pine plantations has been common throughout the range of all barrens types, and this practice is continuing.

In Wisconsin, the Sharp-tailed Grouse (Wisconsin Special Concern) requires relatively large areas of barrens habitat to maintain viable breeding populations. The species' future here remains uncertain. Photo by Brian Collins.

Rolling topography on sandy glacial outwash supports barrens vegetation composed of prairie grasses and forbs, oak grubs and other deciduous brush, and scattered jack pine. Namekagon Barrens, Burnett County. Photo by Eric Epstein, Wisconsin DNR.

Slender glass lizard (Wisconsin Endangered) inhabits sandy oak savannas, including oak and pine barrens, and open woodlands. Photo by A.B. Sheldon.

Some of Wisconsin's best examples of the Oak Barrens community occur at Fort McCoy Military Reservation. Numerous rare species inhabit this site. Monroe County. Photo by Eric Epstein, Wisconsin DNR.

Other communities grouped with the barrens types include the extremely rare Great Lakes Barrens, limited in Wisconsin to a few stands along lakes Superior and Michigan; the mixed Pine-Oak Barrens, which needs additional study and description in Wisconsin; and the Bracken Grasslands, semi-natural upland openings within the ***matrix*** of the northern forests, occurring primarily in northeastern and north central Wisconsin. Unmanaged Bracken Grasslands are often associated with topographic depressions known as frost pockets.

Current Assessment of Oak and Pine Barrens Communities

Pine barrens covered about 2.3 million acres, or approximately 7% of Wisconsin's total area, at the time of major Euro-American settlement in the mid-19th century. Oak barrens covered roughly 1.8 million acres, or 5% of the total Wisconsin landscape before Euro-American settlement. As of 2009, approximately 15,000 acres of relatively intact pine and oak barrens remained at 94 sites (Figure 2.9) (WDNR 2009). Of this total, oak barrens occur on about 5,100 acres at 38 sites. Total barrens acreage, including highly degraded but potentially restorable sites, is currently estimated at roughly 50,000 acres. Most of these lands have been severely disturbed by great increases in woody cover due to prolonged periods of fire suppression; colonization by highly invasive plants such as leafy spurge, spotted knapweed, black locust (*Robinia pseudoacacia*), and Eurasian honeysuckles; overgrazing; past attempts to grow crops during which the sandy, highly erodible barrens soils were plowed; or conversion to pine plantation monocultures. On the driest sites with the most infertile soils, some of these attempted conversions to plantations have failed, and these sites may offer some of the better opportunities for large-scale restorations.

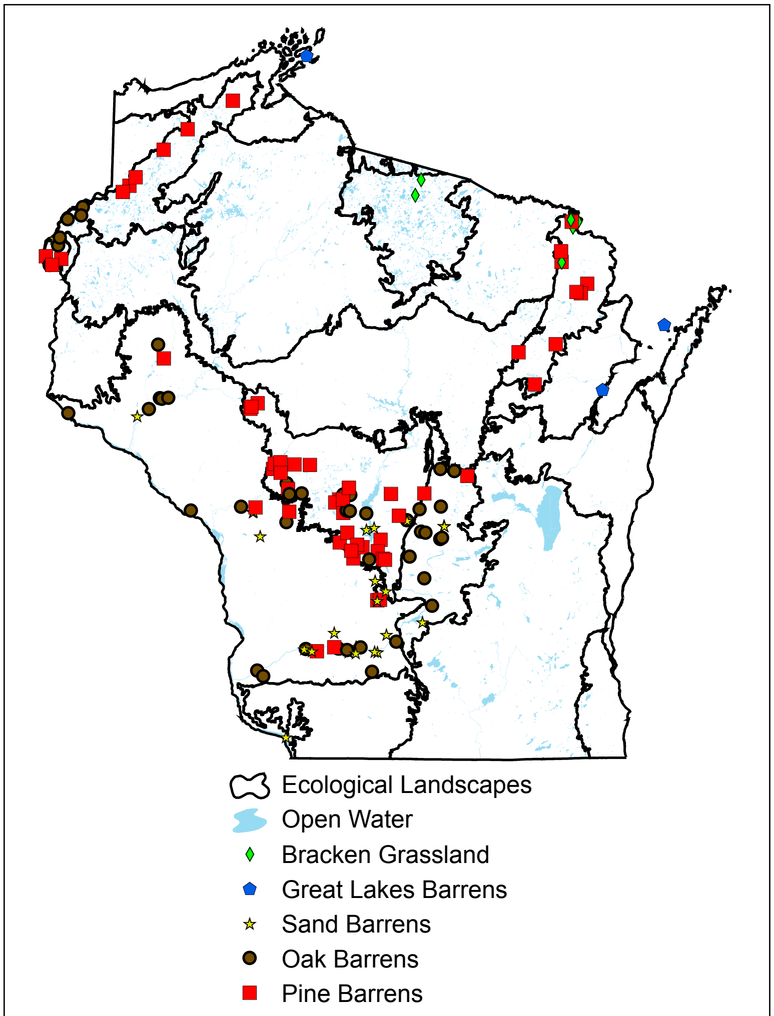

Figure 2.9. *Barrens and Bracken Grassland occurrences in Wisconsin, 2009 (WDNR 2009).*

In some areas, such as in parts of northwestern and central Wisconsin, surveyor's notes from the federal General Land Office's public land surveys in the mid-1800s indicated that true pine savannas were present. These were characterized by large, widely spaced trees (usually red pine) and an open understory. Pine barrens featuring such structural characteristics are now entirely absent from our state (except for a single example of the floristically distinctive Great Lakes Barrens from Ashland County).

With a few exceptions, most remaining barrens exist as relatively small, isolated fragments on approximately a dozen state or federally managed sites (the latter includes Trempealeau National Wildlife Refuge, Necedah National Wildlife Refuge, part of the Chequamegon-Nicolet National Forest, and Fort McCoy Military Reservation). State partnerships with county governments (e.g., Burnett, Douglas, Eau Claire, and Jackson counties) have enabled the restoration and management of key barrens sites in central, west central, and northwestern Wisconsin. Restoration actions and better-coordinated timber sale planning have increased the management compatibility and effective scale of some barrens sites.

The persistence of remnants and the apparently successful restoration of overgrown or otherwise degraded sites are among the indicators that additional areas in the appropriate landscape settings have the potential to restore conditions that will support the unique assemblages of plants and animals that are characteristic of barrens communities.

Bracken Grasslands have significantly declined due to decades of fire control, tree planting, and the vigorous sprouting of aspen following clearcutting of adjacent forests. As a result, they have often converted to forest except on anomalous sites such as frost pockets where growing season frosts and perhaps the allelopathic properties of bracken fern have inhibited tree growth. Severe post-logging slash fires occurred on some sites and damaged the soils by incinerating the organic matter, another of the factors that may inhibit productivity, including tree growth.

Nevertheless, all barrens remnants provide potentially significant habitat for declining barrens species, including birds, reptiles, butterflies, moths, and beetles, and are worthy of conservation attention. Relatively large sites with high potential to manage for or increase the jack pine component may support rare species such as the Connecticut Warbler (*Oporornis agilis*) and, especially, the U.S. Endangered Kirtland's Warbler, which has recently been found breeding in central Wisconsin (first in 2007 and then in every subsequent year).

Issues of Composition, Structure, and Function

The composition, structure, and function of barrens communities depend on the type and frequency of disturbance, land use context and history, and the location, size, and connectivity of remaining sites. Most of the northern Pine Barrens have succeeded to closed canopy Northern Dry Forest or have been converted to pine plantations. Most of the southern Oak Barrens have succeeded to Southern Dry Forest, have been converted to pine plantations, or have been converted to cropland. The development and spread of center pivot irrigation, especially on the large river terraces and in central Wisconsin, has been a significant factor in the conversion of Oak Barrens to cropland. Residential and infrastructure development on the river terraces in the Western Coulees and Ridges Ecological Landscape have also severely fragmented or destroyed barrens communities.

The conversion of barrens remnants to pine plantations continues on public and some private lands; on public lands the conversion process includes ***furrowing***, scalping, and herbicide applications. This results in significant, if not total, losses of characteristic barrens composition, structure (including horizontal patch structure), and function.

Composition

The major composition problem is reduced representation by native grasses, forbs, and shrubs and associated fauna, especially for the now rare more open variants of the barrens community. Most remaining barrens sites are too small and isolated to ensure long-term viability for populations of all of their characteristic native plants and animals. Stand isolation makes species loss difficult to overcome because recolonization is difficult and for some species may be impossible without active intervention. Floristically rich barrens remnants need to be identified range wide and the data made available to managers, planners, and NGOs.

In addition to the loss of native species, highly aggressive exotic invasive plants such as spotted knapweed and leafy spurge have spread rapidly into and are now serious management problems in many barrens communities. This includes stands identified as among the best of their type and which now receive management attention that is intended to conserve their unique biota. Dominance by the native Pennsylvania sedge (*Carex pensylvanica*) has been noted as a management problem at some sites because it is capable of forming dense sods that can exclude or inhibit the growth of other native plants.

Of species associated with and persisting in barrens remnants, the Sharp-tailed Grouse is among the most area-sensitive, needing an estimated 10,000 acres or more of suitable habitat to support a viable population. Globally rare species include the Karner blue butterfly, Kirtland's Warbler, prairie fameflower, and clustered poppy mallow (*Callirhoe triangulata*). Wisconsin likely has the best opportunities in North America to protect the Karner blue butterfly and possibly the prairie fameflower.

Barrens vegetation was prevalent here until recently. An aggressive program of tree planting has reduced the patches of native barrens to small, isolated remnants embedded within a matrix of dense monotypic conifer plantations. Douglas County. Photo by Eric Epstein, Wisconsin DNR.

The thumb of Wisconsin DNR biologist Gregor Schuurman became an attractive perch for this Karner blue butterfly, a U.S. Endangered species. Photo by Gregor Schuurman, Wisconsin DNR.

Structure

The predominant structural issue is the dominance of trees and other woody growth with reduced representation of native grasses, forbs, shrubs, and associated fauna.

Many managed stands are now structurally homogeneous. The full historical range of structural variability characteristic of the barrens communities, from open "brush prairie," to many variants of semi-open pine or oak savanna, to patches of dense dry forest, is now missing from most managed barrens complexes. This is a critical restoration issue if the full spectrum of barrens-dependent plants and animals is to be conserved. However, restoration should not come at the expense of the large patches of "brush prairie" needed by area-sensitive habitat specialists such as the Sharp-tailed Grouse. Additional attention is needed at the inventory, planning, and management levels to ensure better representation of missing structural elements.

Barrens restoration, Rynearson Flowage, Necedah National Wildlife Refuge, Juneau County. Photo by Eric Epstein, Wisconsin DNR.

This mixed oak and pine barrens has been restored through the use of mechanical brush and tree removal and prescribed burning. The scattered trees provide habitat for species such as Red-headed Woodpecker, Orchard Oriole (Icterus spurius), *and Eastern Bluebird* (Sialia sialis). *Several invertebrates associated with barrens benefit from the filtered shade of the remaining trees. Photo by Armund Bartz, Wisconsin DNR.*

There is often a very sharp contrast and abrupt edge between intensively managed barrens that are burned frequently and regularly and the surrounding vegetation, which is typically dense forest that is managed to maximize fiber production. This situation leaves some species without suitable habitat, creates barriers to dispersal for others, and can result in logistical difficulties for managers because of the high flammability of the surrounding vegetation.

Stand isolation is a structural as well as a compositional problem since the landscape between patches of barrens habitats is now often "hostile" or even impassable to some species. There is a need, and at some sites there is definitely an opportunity, for the creation of travel and dispersal corridors that can at least periodically connect ***disjunct stands***.

Function

The predominant functional problem is the lack of periodic fire. Better understanding of frequency, severity, scale, need for unburned refugia, and timing of the prescribed fires is needed if the entire barrens community is to be managed successfully and maintained.

Lack of connectivity between stands inhibits or prevents immigration and emigration, with lost opportunities for genetic exchange. In a fragmented landscape, the chances of a given species recolonizing a potentially suitable but now isolated habitat patch from which it has been lost are very low.

Land Use and Environmental Considerations

Some of the major issues that should be considered when planning management for Oak and Pine Barrens are that many former Oak and Pine Barrens have become forests, been planted to pine monotypes, or converted to agriculture. Lack of periodic fire inhibits restoration and maintenance of Oak and Pine Barrens. There are some Oak and Pine Barrens remnants on large public land holdings that can be managed to perpetuate this community type.

Prescribed burning is being used here to reduce woody shrub and sapling cover and promote growth of native understory grasses and forbs. Photo by Armund Bartz, Wisconsin DNR.

- Most of the former Oak Barrens stands in central and southern Wisconsin now support extensive pine plantations, irrigation-dependent agriculture, or subdivisions, or they have succeeded to dense, dry oak forests. In northern Wisconsin extensive acreages of Pine Barrens have been converted to monotypic plantations of red pine in recent decades.
- Some remnants occur on relatively large tracts of public land such as Fort McCoy, the Black River State Forest, Necedah National Wildlife Refuge, and the Jackson County Forest.
- Lack of regular burning continues to be a limiting factor in barrens restoration and maintenance. Isolation, small patch size, increased presence of invasive species, and landscape context can all be significant limiting factors.
- To most of the public, barrens do not seem to have the same aesthetic appeal as forests. However, groups, institutions, and communities interested in native flora, fauna, and vegetation; in blueberry picking; and in using barrens areas for hunting, bird-watching, hiking, skiing, horse riding, and other open-area pursuits are among the many potential supporters of restoration actions.

Statewide Ecological Opportunities for Oak and Pine Barrens Communities

Oak Barrens and Pine Barrens are among the more resilient natural communities (especially compared with other savanna communities on more mesic sites such as Oak Openings). Under some circumstances, including initial stand condition, barrens may be relatively easy to restore and can respond well to careful management via controlled burns, tree thinning, and brush removal. They are also less suitable for most agricultural uses than some other community types and have not been as desirable for residential development (exceptions occur on some of the river terrace barrens such as those along the Mississippi River, which have experienced significant exurban and some industrial development in recent years). However, the explosive spread of invasive plants in recent years has greatly complicated restoration efforts, so the preceding statements must be tempered with caution. Also, in recent years it has become common to treat barrens communities with herbicides as part of the site preparation to convert stands to pine plantations. This results in the loss of native barrens species and can make restoration very difficult and expensive because it creates the need to reintroduce plants and dependent animals that have been inadvertently lost from restorable stands.

The best opportunities for managing barrens communities exist in northwestern, northeastern, central, and southwestern Wisconsin.

Woody vegetation on these ancient sand dunes is being managed with prescribed fire and mechanical brushing to restore oak barrens habitat at Necedah National Wildlife Refuge, Juneau County. Photo by Eric Epstein, Wisconsin DNR.

Ecological Opportunities by Ecological Landscape

The best opportunities for preservation, enhancement, and restoration of barrens communities can be found in the following ecological landscapes (see Figure 2.9 for occurrences of Pine and Oak Barrens):

- Northwest Sands
- Central Sand Plains
- Western Coulees and Ridges
- Northeast Sands
- Central Sand Hills
- Northern Highland (Bracken Grasslands only)
- Superior Coastal Plain (Great Lakes Barrens only, on sandspits)

To restore and protect the full species composition and structural variability of the barrens communities, sites must be managed across the historical range of the communities and should include missing structural variants and patch sizes. Small restoration efforts can be valuable, but at least a few must approach or exceed 10,000 acres to accommodate species requiring large areas, such as Sharp-tailed Grouse. The best large- and medium-scale opportunities include the following:

- **Northwest Sands Ecological Landscape.** The Northwest Sands Pine Barrens Ecosystem Restoration and Management Initiative is a landscape-scale planning project to promote pine and oak barrens management in northwestern Wisconsin and includes many of the properties below.
  - Fish Lake Wildlife Area (Burnett County)
  - Crex Meadows Wildlife Area (Burnett County)
  - Kohler-Peet Barrens (Burnett County)
  - Namekagon Barrens Wildlife Area (Burnett County)
  - Fenton Lake Barrens and Firebreak (Burnett County)
  - Sterling Barrens State Natural Area (Polk County)

- Douglas County Wildlife Area
- Moquah Barrens Wildlife Area (includes Moquah Barrens ***Research Natural Area***, Bayfield County)
- Brule River State Forest (southern part of the state forest, Douglas County)

■ **Northeast Sands Ecological Landscape**

- Spread Eagle Barrens State Natural Area (Florence County)
- Dunbar Barrens State Natural Area (Marinette County)
- Athelstane Barrens (Marinette County)

■ **Central Sand Plains Ecological Landscape**

- Necedah National Wildlife Refuge (Juneau County)
- Black River State Forest (Jackson County)
- Meadow Valley Wildlife Area (Juneau County)
- Sandhill Wildlife Area (Wood County)
- Wood County Wildlife Area
- Jackson County Forest
- Eau Claire County Forest

■ **Western Coulees and Ridges Ecological Landscape**

- Lower Wisconsin Riverway (including the Mazomanie Oak Barrens, Spring Green Preserve, Millville State Wildlife Area, and Gotham Jack Pine Barrens; Crawford, Grant, Richland, Iowa, Sauk, and Dane counties) (see Figure 2.9).
- Lower Chippewa River (Buffalo, Dunn, and Pepin counties)
- Fort McCoy and Fort McCoy Barrens State Natural Area (Monroe County)
- Trempealeau National Wildlife Refuge (Trempealeau County)
- North Bend Bottoms Wildlife Area (Jackson County)

Small-scale barrens management efforts will be needed in additional areas to preserve rare species and distinctive variants of the community. For example, rare butterflies may persist on a relatively small site if large populations of important food and nectar plants are present. Rare plants may persist as long as an appropriate disturbance regime exists or can be implemented, and the necessary pollinators are present.

Good opportunities to conserve barrens at small to moderate scales (tens to hundreds of acres) occur in the west central counties of Dunn and Eau Claire, especially along the lower Chippewa and Eau Claire rivers and some of their tributaries. Recent inventory work has led to the discovery of good quality barrens remnants on sand terraces bordering the Black River. Opportunities also occur in the Central Sand Hills Ecological Landscape and in parts of the Northeast Sands Ecological Landscape in Marinette, Florence, and Oconto counties.

New Findings, Opportunities, and Conservation Needs

- The Karner blue butterfly is a U.S. Endangered species that is rare nationwide but is relatively common in parts of Wisconsin where Pine Barrens, Oak Barrens, Oak Openings, Sand Prairies, and mowed or brushed rights-of-way corridors support wild lupine (*Lupinus perennis*), the only food plant of the Karner blue caterpillar. More Karner blue butterflies live in Wisconsin than anywhere else in the world. The Wisconsin Karner Blue Butterfly Habitat Conservation Plan (HCP) is based on a legal agreement between the U.S. Fish and Wildlife Service, the Wisconsin DNR, and an array of public and private land managers. Forty major land managers participate in the HCP as partners, including representatives from the forest industry, utility companies, and roadway management authorities. The partnership works together making land-use decisions to ensure the Karner blues' survival (WDNR 2009).
- The recent discovery that the U.S. Endangered Kirtland's Warbler is breeding successfully in young mixed jack and red pine forest habitats in central Wisconsin is very exciting and provides a further incentive to more thoroughly examine the opportunities and needs for barrens ecosystem conservation in our state.
- Selected species strongly associated with barrens across taxa (e.g., plants, invertebrates, herptiles, birds, mammals) should be monitored throughout the geographic range of the barrens communities.
- Educational efforts are needed that present the history of the barrens in the Upper Midwest and continentally, their demise and almost total loss from today's landscapes, the relationship with fire ("wild" and prescribed), the rich ***biota*** they support, and the key roles these natural communities play in conserving our native biota.
- A statewide inventory of barrens and dry forests is needed to identify and assess the condition, cover types, context, sizes, and developmental stages of existing remnants and to locate and prioritize potential restoration sites based on historical or other pertinent information on barrens and dry forests.
- The inventory should be two-fold and closely coordinated. A field component is needed along with an examination of secondary sources such as satellite imagery, air photos, soil maps, topographic maps, the public land survey, land cover, and published research reports. Interview should be conducted with persons knowledgeable about barrens and dry forest ecosystems.
- Conservation plans should be developed with appropriate landowners to ensure that there is adequate representation of patch sizes (especially of the now very scarce larger patch sizes), cover types, developmental stages, and connectivity between remnants.

- Restoration sites need to be identified. Highly fragmented or parcelized sites and those overrun with invasive species will be much more difficult and expensive to restore than larger, less fragmented sites in relatively good condition, which can be managed more efficiently. The development of criteria that will aid in the identification, evaluation, and prioritization of sites with restoration potential is an associated need as an aid to decision making.
- Maps of existing barrens community and barrens species occurrences should be overlain and the scale of management opportunities refined to address issues of population viability and the needs of area-sensitive species and those species for which at least periodic connections between patches of suitable habitat are desirable.
- To better depict barrens-dominated areas, the original land survey notes or maps made from those surveys by Finley (1976), Mladenoff et al. (2009), and others should be examined and areas occupied by barrens and dry forest vegetation matched up with sandy soils and topography that would have facilitated fire behavior most likely to have maintained barrens ecosystems.
- Methods to better integrate plans that are more compatible with aspects (e.g., scale, timing, management unit configuration) of dry forest management should be developed. On some state and federally owned properties, barrens and dry forests can and should be managed in concert. Such management may also be possible and supported on state and county forestlands that are certified.

Scientific names of species mentioned in the oak and pine barrens communities assessment.

Common name	Scientific name
Bearberry	*Arctostaphylos uva-ursi*
Black bear	*Ursus americanus*
Black locust	*Robinia pseudoacacia*
Black oak	*Quercus velutina*
Blanding's turtle	*Emydoidea blandingii*
Blueberries	*Vaccinium* spp.
Bracken fern	*Pteridium aquilinum*
Brittle prickly pear	*Opuntia fragilis*
Bur oak	*Quercus macrocarpa*
Cherries	*Prunus* spp.
Clustered poppy mallow	*Callirhoe triangulata*
Common juniper	*Juniperus communis*
Connecticut Warbler[a]	*Oporornis agilis*
Eastern Bluebird	*Sialia sialis*
Eastern massasauga rattlesnake	*Sistrurus catenatus catenatus*
Eurasian honeysuckles	*Lonicera tatarica, Lonicera* x *bella, L. mackii, L. morrowii*
False heather	*Hudsonia tomentosa*
Frosted elfin butterfly	*Incisalia irus*
Hazelnut	*Corylus americana* and *C. Cornuta*
Hill's (northern pin) oak	*Quercus ellipsoidalis*
Jack pine	*Pinus banksiana*
Junipers	*Juniperus* spp.
Karner blue butterfly	*Lycaeides melissa samuelis*
Kirtland's Warbler	*Setophaga kirtlandii,* listed as *Dendroica kirtlandii* on the Wisconsin Natural Heritage Working List
Leafy spurge	*Euphorbia esula*
New Jersey tea	*Ceanothus americanus*
Northern blue butterfly	*Lycaeides idas*
Orange hawkweed	*Hieracium aurantiacum*
Orchard Oriole	*Icterus spurius*
Pennsylvania sedge	*Carex pensylvanica*
Phlox moth	*Schinia Indiana*
Prairie fameflower	*Talinum rugospermum*
Prairie red-root	*Ceanothus herbaceus*
Prairie willow	*Salix humilis*
Red pine	*Pinus resinosa*
Rough white lettuce	*Prenanthes aspera*
Sand violet	*Viola fimbriatula*
Serviceberry	*Amelanchier* spp.
Sharp-tailed Grouse	*Tympanuchus phasianellus*
Slender glass lizard	*Ophisaurus attenuatus*
Spotted knapweed	*Centaurea biebersteinii*
Sweet-fern	*Comptonia peregrina*
Ternate grape fern	*Botrychium rugulosum*
White-tailed deer	*Odocoileus virginianus*
Wild lupine	*Lupinus perennis*
Wild Turkey	*Meleagris gallopavo*
Woolly milkweed	*Asclepias lanuginosa*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologist Union.

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Northern Forest Communities

Community Description

Wisconsin's northern forest communities are found mostly north of the Tension Zone. Before Euro-American settlement, prairies and oak savannas of the south transitioned into the mixed deciduous-coniferous forests of the north near the Tension Zone. Today, the most apparent transition is from widespread agricultural uses in the south to more continuous forest cover in the north. This section focuses mostly on the Wisconsin portion of Province 212 (Figure 2.10), as identified by the National Hierarchical Framework of Ecological Units (Cleland et al. 1997).

Although north of the Tension Zone, the area along Lake Michigan is distinct from the rest of the northern forest due to the lake's climatic moderation and the influence of calcareous glacial till and the ***Niagara Escarpment*** underlying eastern Wisconsin. The shorter growing season in northern Wisconsin for areas away from the Great Lakes makes it less suitable for agriculture and allows forests to predominate. Forests occupy 64% (11.4 million acres) of Province 212 (USFS 2010). Although Province 212 comprises roughly half (52%) of the state, the forests of Province 212 represent 68% of Wisconsin's total ***timberland***. Province 212 is less populated and less developed than the southern part of the state, although home construction is increasing in many areas.

Today's northern forest is characterized by broadleaf deciduous tree species, with a lesser proportion of conifers. About 30 native tree species can be found in the northern forest. Tree species composition at each locality varies depending on characteristics of the glacial landform and associated soils providing the substrate, past and current human activities, natural disturbances, and stresses such as herbivory. Maps of historical and current land cover are found in Appendix G, "Statewide Maps," in Part 3 of the book ("Supporting Materials").

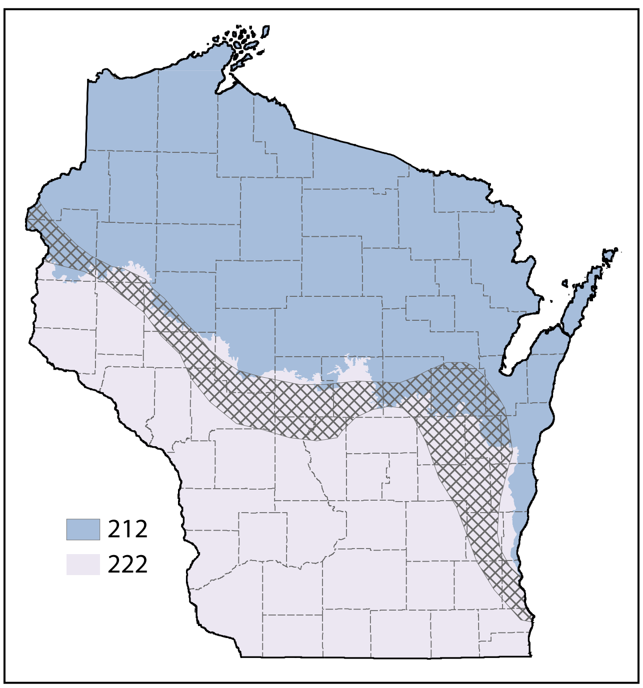

Figure 2.10. *Location of Provinces in Wisconsin (Cleland et al. 1997), along with estimated location of the Tension Zone (crosshatched), adapted from Curtis (1959).*

Current Vegetation

Northern forests are often characterized using cover types that can be derived from U.S. Forest Service Forest Inventory and Analysis (FIA) data. Although there are several limitations to using FIA data, they are our best source to estimate forest cover acreages over very broad scales (see Appendix C, "Data Sources Used in the Book," in Part 3, "Supporting Materials"). The FIA estimates for cover provided here are based on 2008 data (USFS 2010). General descriptions of the major northern forest cover types are given below, and Figure 2.11 provides the relative abundance of each type in northern Wisconsin.

- Maple-basswood is the most common northern forest cover type, occupying 18% of the land area of Province 212. This community includes sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), red maple, American basswood (*Tilia americana*), white ash (*Fraxinus americana*), northern red oak (*Quercus rubra*), quaking aspen (*Populus tremuloides*), yellow birch (*Betula alleghaniensis*), and eastern hemlock (*Tsuga canadensis*) (Curtis 1959). American beech is present only in the eastern portion of the state. This group corresponds to the Northern Mesic Forest community type.

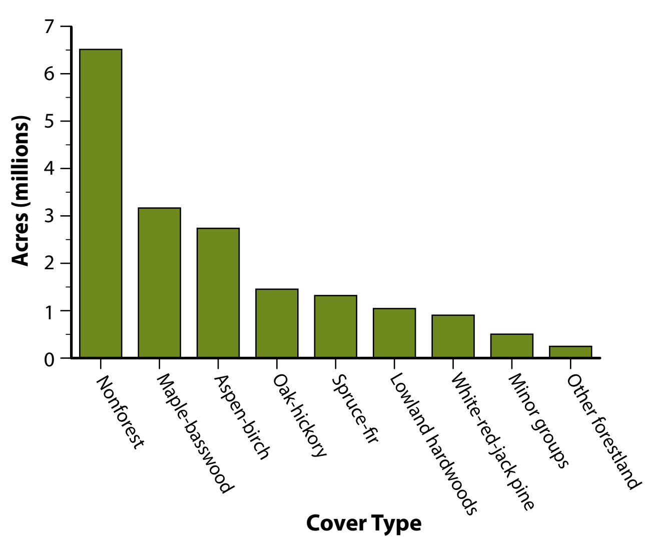

Figure 2.11. *Major cover types in Province 212 from Forest Inventory and Analysis (FIA) data (USFS 2010).*

- Aspen-birch is the second most common forest type group, occupying 15% of the land area of Province 212. Quaking and big-tooth aspen, white birch (*Betula papyrifera*), red maple, and balsam fir (*Abies balsamea*) are important species in this forest type group (Curtis 1959). The majority of the aspen forests in the state are not recognized by community types because they are early successional transitional stages that would succeed to other types in the absence of additional disturbance. An exception to this is the Boreal Forest, a community type that has an aspen component but is almost entirely restricted to two of Wisconsin's ecological landscapes. Much of the former Boreal Forest is now managed for aspen, and the representation of the formerly dominant conifers—eastern white pine (*Pinus strobus*), white spruce (*Picea glauca*), and balsam fir—has been greatly reduced.

Second-growth mesic hardwood forests now comprise the prevalent forest cover in much of northern Wisconsin. This stand in the eastern part of the state contains a substantial component of American beech, which is limited to Wisconsin's easternmost counties. Beech, now declining in Wisconsin, is important because of its size, longevity, appearance, potential dominance, and the mast *it produces in some years. Marinette County. Photo by Drew Feldkirchner, Wisconsin DNR.*

At a few locations within the Superior Coastal Plain Ecological Landscape, boreal conifers such as white spruce and balsam fir are common quaking aspen associates. Aspen remains widespread and abundant across much of northern Wisconsin; boreal forest is rare and localized and can only be maintained in a few areas. Brule River State Forest, Douglas County. Photo by Eric Epstein, Wisconsin DNR.

Other forest type groups found in the northern forest community are as follows:

- Oak-hickory (8% of land area of Province 212), including forests dominated by northern red oak, white oak (*Quercus alba*), and Hill's (northern pin) oak, with components of red maple, aspen, eastern white pine, black oak nearer the Tension Zone, bur oak, or black cherry. Hickories (*Carya* spp.) are a minor component of northern forests (Curtis 1959). This group can include a diversity of community types, varying with locations and landforms. The most common corresponding community types are Southern Dry-mesic Forest and Northern Dry Forest.
- Spruce-fir (7% of land area of Province 212), including white spruce, balsam fir, black spruce (*Picea mariana*), northern white-cedar (*Thuja occidentalis*), and tamarack (*Larix laricina*). This type includes the swamp conifer and boreal forest types described by Finley (1976) and corresponds to Northern Wet Forest, Black Spruce Swamp, Tamarack (Poor) Swamp, and Northern Wet-mesic Forest community types.
- Pine forests of eastern white, red, and jack pine (5% of land area of Province 212). This group corresponds to Northern Dry-mesic Forest (white and red pine dominated) and Northern Dry Forest (jack pine and pin oak dominated).
- Lowland hardwoods with black ash (*Fraxinus nigra*), green ash (*Fraxinus pennsylvanica*), red maple, and silver maple (*Acer saccharinum*) (6% of land area of Province 212). Silver maple is found only in floodplains associated with larger rivers. American elm (*Ulmus americana*) is relatively common in lowland forests as saplings or small trees of 20 to 25 feet in height but seldom reaches the forest canopy. This group corresponds to the Hardwood Swamp and Floodplain Forest community types. Examples of Floodplain Forest in the northernmost ecological landscapes tend to have greatly reduced representation of canopy species.
- Nonforested types comprise 36% of Province 212 and are not assigned cover type categories by FIA data. These types include barrens, grasslands (typically agricultural fields or former fields), wetlands, and aquatic communities. Nonforested types are described in other sections of this chapter.

Natural Community Types

There are 12 northern forest natural community types in Wisconsin (Table 2.1). In general, these types occur north of the Tension Zone, but there are some notable exceptions, such as the Central Sand Plains Ecological Landscape where both northern and southern community types can be found. These natural community types are defined by plant species assemblages and do not directly translate to the forest cover type groups used by Forest Inventory and Analysis (Schmidt 1997), which rely on overstory dominants. However, matching forest cover types to related natural community types is easier for the northern forest communities than most other groups of natural community types. See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," for natural community descriptions.

Forested natural community types often occur with nonforested types comprising a community mosaic or continuum. For example, Northern Dry Forest can often be associated with Pine Barrens, a globally rare community type that provides habitat for many rare species. Other nonforested or sparsely forested areas of northern Wisconsin may contain grasslands (largely agricultural fields or old fields), wetlands, or aquatic communities. See the grasslands, wetlands, and aquatic communities sections of this chapter for more information on these groups of communities.

Historical Vegetation of the Mid-1800s

Historically, the northern forests were much different than today. The last glacial period ended in Wisconsin about 10,000 to 12,000 years ago, and vegetative succession occurred as the land warmed and species moved northward. At about 3,000 years ago, the tree species found in today's forests were all present in northern Wisconsin (Davis et al. 1993). However, dominance of the various species groups shifted in response to climatic fluctuations and disturbance regimes during the past 3,000 years in ways that cannot be completely documented. Human-caused disturbances have been the major source of change in these communities for at least 150 years.

Below are Finley's forest type categories for northern Wisconsin prior to Euro-American settlement (Finley 1976). See Appendix C, "Data Sources Used in the Book," for more information about these data. Maps depicting forest cover of the mid-1800s are also available in Appendix G, "Statewide Maps," in Part 3 ("Supporting Materials").

■ **Mixed Coniferous-Deciduous Forest.** Mixed coniferous-deciduous forest was the dominant forest type and included a number of different forest types:

- Jack pine, ***scrub oak***, and barrens covered about 1.5 million acres (8% of the land area of Province 212). This forest

Table 2.1. *Northern forest natural community types with state and global ranks as of 2011 (see the Wisconsin Natural Heritage Working List, http://www.dnr.wi.gov/, keyword "NHI," for more information).*

	State Rank[a]	Global Rank[b]
Upland Forests		
Boreal Forest	S2	G3?
Mesic Cedar Forest	S1	G3?
Mesic Floodplain Terrace	S2	GNR
Northern Dry Forest	S3	G3?
Northern Dry-mesic Forest	S3	G4
Northern Mesic Forest	S4	G4
Wetland Forests		
Black Spruce Swamp	S3?	G5
Forested Seep	S2	GNR
Hardwood Swamp	S3	G4
Northern Wet Forest	S4	G4
Northern Wet-mesic Forest	S3S4	G3?
Tamarack (Poor) Swamp	S3	G4

[a]**State ranks:**

S1 – Critically imperiled in Wisconsin because of extreme rarity, typically five or fewer occurrences and/or very few (<1,000) remaining individuals or acres, or because of some factor(s) making it especially vulnerable to extirpation from the state.

S2 – Imperiled in Wisconsin because of rarity, typically 6 to 20 occurrences and/or few (1,000–3,000) remaining individuals or acres, or because of some factor(s) making it very vulnerable to extirpation from the state.

S3 – Rare or uncommon in Wisconsin, typically 21 to 100 occurrences and/or 3,000–10,000 individuals.

S4 – Apparently secure in Wisconsin, usually with >100 occurrences and >10,000 individuals.

S5 – Demonstrably secure in Wisconsin and essentially ineradicable under present conditions.

[b]**Global ranks:**

G1 – Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

G2 – Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3 – Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single state or physiographic region), or because of other factor(s) making it vulnerable to extinction throughout its range; typically 21 to 100 occurrences. A question mark indicated that there is a level of uncertainty regarding the global rank and G3 is the most likely rank, based on current information.

G4 – Uncommon but not rare (although it may be quite rare in parts of its range, especially at the periphery) and usually widespread. Typically >100 occurrences.

G5 – Common, widespread, and abundant (although it may be quite rare in parts of its range, especially at the periphery). Not vulnerable in most of its range.

GNR – Not ranked.

type included a variety of successional and structural states, ranging from dense jack pine forests, to areas sparsely forested with stunted oaks or oak-pine mixtures, to recently burned areas with few live trees remaining. The oak species were usually northern pin oak or bur oak. Other scattered tree species sometimes found in these forests included red and eastern white pine, red maple, aspen, and white birch. These forests were restricted to the xeric portions of sandy outwash plains and glacial lakebeds. Much of the Northwest Sands Ecological Landscape was covered by this type. It also occupied large areas in the Northeast Sands and Central Sand Plains (located south of the Tension Zone) Ecological Landscapes. Species were fire adapted, and vegetative communities were subject to frequent, intense fires. Insect outbreaks (e.g., jack pine budworm [*Choristoneura pinus*]) often affected extensive areas of forest and contributed to fuel build-ups and higher fire intensity. This forest type corresponds to the Northern Dry Forest and Pine Barrens natural community types.

- White pine-red pine forest occupied about 1.5 million acres (8% of the land area of Province 212). This is considerably less than logging-era folklore has led many people to believe. The Northern Highland Ecological Landscape had the largest contiguous area of pines, but pines also occurred along the margins of the Northwest Sands Ecological Landscape, throughout the Northeast Sands Ecological Landscape, and along the Tension Zone. These forests were mostly restricted to sandy areas formed by glacial outwash or lakebeds in the northernmost part of the area, but they also occurred on more productive soils along the Tension Zone where fire disturbance was extensive. Fire was the major natural disturbance that regenerated red and white pine forests, although insect outbreaks and windthrow often contributed to fuel buildup that led to fires. While catastrophic fires led to stand replacement, less intense fires often created open forest understories or barrens and savannas. This forest type corresponds primarily to the Northern Dry-mesic Forest community type.
- Hemlock-sugar maple-yellow birch-pine forest occupied about 6.2 million acres (32% of the land area of Province 212). This vegetative type, often referred to as the hemlock-hardwood forest, was the largest and most characteristic forest of northern Wisconsin at the time of the federal General Land Office (GLO) public land survey. Overall, eastern hemlock made up about 21% of the trees, and yellow birch and sugar maple accounted for another 17% each, according to recent analyses of GLO data (L. Schulte, University of Wisconsin-Madison, personal communication). Forests were patchy, dominated by eastern hemlock in some places and combinations of sugar maple and yellow birch in others. They were mostly found on glacial till plains and moraines in the North Central Forest and the Forest Transition Ecological Landscapes. The glacial till substrate provided nutrients and moisture in moderate amounts as required by these forests, and they were well adapted to the colder climate, which restricted the abundance of many species commonly found south of the Tension Zone. The dominant natural disturbance, on an area basis, was mostly ***gap-phase windthrow*** that disturbed small patches of less than 1/10 acre (Tyrrell 1991). Under this disturbance regime, vast areas of the forest were able to age and become old growth (Frelich 1995). ***Old-growth forests*** featured large quantities of dead wood, trees with cavities and broken branches or trunks, and tip-up mounds on the forest floor (Tyrrell and Crow 1993). Catastrophic blowdowns occurred but impacted less area on average than gap-phase disturbance (Canham and Loucks 1984). There were also impacts from mid-scale wind disturbances, but the relative extent of this type of disturbance is unknown. Investigations of the age-class structure of old-growth forests show a periodicity or clustering around several age-class groups, indicating that trees regenerated at intervals, rather than continuously (Bourdo 1983, Loucks 1983, Frelich and Lorimer 1985). Two reasons suggested for this periodicity are competition for scarce soil moisture and nutrients (Loucks 1983) or mid-scale wind disturbances (C. Lorimer, University of Wisconsin-Madison, personal communication). Other factors, such as drought and insect outbreaks, may also have contributed. This forest type corresponds to the Northern Mesic Forest natural community type.
- Sugar maple-yellow birch-pine forest occupied about 2.1 million acres (11% of the land area of Province 212). This forest type was found south and west of the hemlock/hardwood type. The type was classified separately from the hemlock-hardwoods because eastern hemlock is absent, as its range ends in Wisconsin due to climatic changes. Sugar maple-dominated forests may have been more associated with the richer glacial moraines because sugar maple is more nutrient demanding than eastern hemlock. The disturbance regime was similar to that of the hemlock-hardwood forest, and these hardwood forests were predominantly in an old-growth condition at the time of the GLO public land survey. This forest type corresponds to the Northern Mesic Forest natural community type.
- Beech-hemlock-sugar maple-yellow birch-pine forest occurred on about 950,000 acres in northeast Wisconsin near Lake Michigan (5% of the land area of Province 212), and the beech-sugar maple-basswood-oak forest occupied 1.2 million acres (7% of the land area of Province 212). This forest type is very similar to the sugar maple-yellow birch-pine forest but was classified separately due to the presence of beech, a species restricted to the eastern part of Wisconsin, presumably due to climatic conditions. The disturbance regime and age distribution at the time of the GLO public land survey was similar to the two previously described hardwood forest types. This forest type corresponds to the Northern Mesic Forest natural community type.

- Aspen-white birch forest, often mixed with pine, occupied about 3.5% to 4.3% of the land area in Province 212, according to recent analyses of GLO public land survey data (Schulte et al. 2002). Finley (1976) mapped slightly less of this type; analysis of his map shows 315,000 acres (2% of land area). Many small patches of this type were scattered in the Northwest Lowlands Ecological Landscape, where they may have resulted from American beaver (*Castor canadensis*) activity and the effects of fire. Several relatively large patches occurred in the Forest Transition Ecological Landscape where they likely originated following fire.

Boreal Forest. Boreal forest was comprised of eastern white pine, white birch, white spruce, balsam fir, tamarack, northern white-cedar, and quaking aspen (WDNR 2001). The boreal forests occupied about 550,000 acres (3% of the land area of Province 212), mostly restricted to areas with unusual ***edaphic*** conditions in the Superior Coastal Plain Ecological Landscape near Lake Superior. Wisconsin's boreal forests resembled the true boreal forests of Canada in some ways, but their composition varied. For example, much of the area was strongly dominated by eastern white pine (D. Mladenoff, University of Wisconsin-Madison, personal communication). There were smaller amounts of boreal forest on shallow soils with dolomite near the surface on the northern Door Peninsula (Northern Lake Michigan Coastal Ecological Landscape), but Finley (1976) classified these as swamp conifers, likely due to the abundance of cedar. The extent of boreal forest in Wisconsin was limited by climatic conditions. Windthrow, fire, and spruce budworm (*Choristoneura fumiferana*) were among the important disturbance agents.

Deciduous Forest, Grassland, and Brush. Most of the deciduous forest types that lacked conifers, as classified by Finley (1976), were found south of or within the Tension Zone, interspersed with extensive savannas and grassland complexes. However, oaks were found in combination with other deciduous species in 10% of Province 212 according to Finley's data.

Wetland Vegetation. Finley (1976) identified three wetland vegetation types in Province 212: lowland hardwoods, marsh and sedge meadows, and swamp conifers. Two of them, the lowland hardwoods type and the marsh and sedge meadow type, occur primarily south of the Tension Zone and, combined, made up less than 1% of Province 212. There were likely, however, large peatland complexes in some areas that are not well represented by the precision of Finley's data. In addition, although GLO public land survey data indicate that black ash was widespread in the north, Finley did not recognize a black ash or hardwood swamp type, so he likely included these natural communities with swamp conifers and lowland hardwoods.

Swamp conifers were the only common and widespread wetlands north of the Tension Zone, based on Finley's assessment (Finley 1976). This type, comprising several current forest cover and natural community types (i.e., forests dominated by northern white-cedar, black spruce, or tamarack), occupied about 2.7 million acres in northern Wisconsin (14% of land area of northern Wisconsin). The majority of the swamp conifer forests were found north of the Tension Zone, with some notable exceptions, including portions of the Central Sand Plains, Central Lake Michigan Coastal, and Southeast Glacial Plains Ecological Landscapes. A wet substrate, either with standing water or a water table close to the land's surface, allowed these conifer forests to develop. Disturbance regimes varied, including flooding, windthrow, and occasionally fire. Boreal Forest was a related conifer-dominated forest type found mostly on the Superior Coastal Plain Ecological Landscape. The swamp conifers cover type classified by Finley (1976) corresponds to the Northern Wet Forest, Black Spruce Swamp, Tamarack (Poor) Swamp, and Northern Wet-mesic Forest community types.

Global/Regional Context

Globally, Wisconsin's northern forest community is part of the temperate deciduous forest biome (Figure 2.12). At about 8,000 years ago, after the Pleistocene epoch, the time period that included the most recent glaciations, this biome covered most of Western Europe, eastern Asia, and eastern North America. Most of the original temperate forest has been cleared (Mathews et al. 2001). In Europe and Asia, deforestation often occurred because of needs for ***fuelwood*** and animal fodder. In North America, forest was cleared primarily to obtain timber and create farmland or, more recently, to provide space for development (Spurr and Barnes 1980).

Wisconsin's northern forest lies primarily within the ecoregion known as the Laurentian Mixed Forest Province (Province 212), as identified by the National Hierarchical Framework of Ecological Units (NHFEU) (Cleland et al. 1997) and shown in Figure 2.12. The ecoregional Province boundary is based on

Figure 2.12. *The Laurentian Mixed Forest Province (212) is a broad-scale level of land classification (Keys et al. 1995). Provinces are based largely on climatic gradients that control the distribution of biomes. Province 212 includes northeast Minnesota, northern Wisconsin, and the Upper Peninsula and northwestern parts of Michigan, along with areas of northern Pennsylvania and New York.*

continental climatic conditions that change in mid-Wisconsin. Climatic differences are reflected in the vegetative changes evidenced along the Tension Zone. The Laurentian Mixed Forest Province includes the northern portions of Minnesota, Wisconsin, and Michigan in the Great Lakes states along with areas of northern Pennsylvania and New York (although some ecologists consider the latter to be climatically distinct and have suggested separating them).

Within Wisconsin, the Laurentian Mixed Forest Province includes the following NHFEU Subsections: Green Bay – Manitowac Upland (212Z), North Central Wisconsin Uplands (212Q), Northern Green Bay Lobe (212T), Northern Highlands (212X), Southern Superior Uplands (212J), Southwest Lake Superior Clay Plain (212Y), and the Western Superior Uplands (212K). See the "National Hierarchical Framework of Ecological Units, Sections, and Subsections in Wisconsin" map in Appendix G, "Statewide Maps," in Part 3 ("Supporting Materials"). Sections are based on climatic differences within a Province and also broadscale glacial features, especially landforms. Many Section boundaries in Wisconsin coincide with the extent of glacial ice lobes during the Wisconsin glaciation. Different glacial lobes are associated with characteristic soil and topographic attributes.

At the time of Euro-American settlement, northern Wisconsin included the largest and most contiguous expanse of hemlock-hardwood forest in the Great Lakes states. Today, the area is still the largest expanse of maple-dominated hardwood forest, offering the best opportunities in the state for maintaining interior forest conditions in large patches. Wisconsin's northern forest is a center of abundance as well as the center of the breeding range for many neotropical migratory songbirds of global significance (Green 1995, Howe et al. 1996) (Figure 2.13). Numerous area-sensitive species are known from the northern forests, including forest interior raptors such as the Northern Goshawk (*Accipiter gentilis*), the Spruce Grouse (*Falcipennis canadensis*), and a diverse array of neotropical migrants (e.g., wood warblers, vireos, thrushes, and flycatchers). In addition, wide-ranging species such as the gray wolf (*Canis lupus*), bobcat (*Lynx rufus*), fisher (*Martes pennanti*), and black bear occur here.

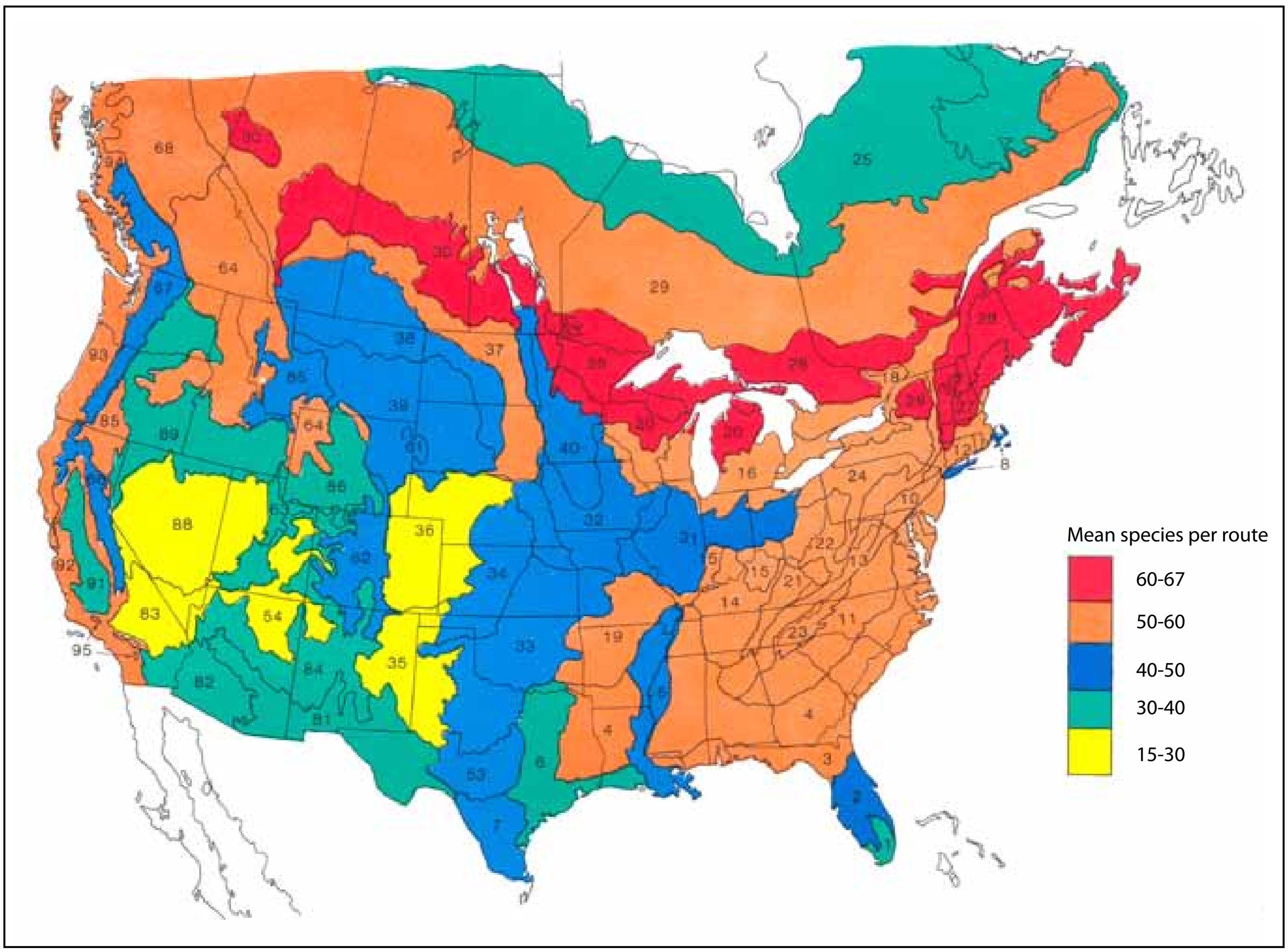

Figure 2.13. *Breeding bird diversity (number of species per breeding bird survey route) by physiographic regions in North America. Northern Wisconsin lies in the physiographic region (shown in red) that has the highest bird species richness of any physiographic region in North America (Robbins et al. 1986).*

An exceptionally diverse and well-defined group of glacial landforms, natural communities, and microhabitats are found interspersed within the northern forests. These features are highlighted in each of the 16 ecological landscapes chapters. A globally rare community type, the Pine Barrens, is found on outwash sands, often in close association with northern forests (see the "Oak and Pine Barrens Communities" section). The Niagara Escarpment is associated with a number of rare plants, land snails, and globally rare community types. Lakes and streams, particularly the concentration of ***kettle lakes*** in some locations, are other significant features of northern Wisconsin. The area also contains the headwaters for most of Wisconsin's major rivers.

Current Assessment of Northern Forest Communities

Today's northern forest communities are very different from the forests that existed prior to Euro-American settlement. Their condition is largely a result of land uses, along with other changes to the physical and biological environment.

Changes Following Euro-American Settlement

Forest ecosystems were drastically disturbed between the 1850s and early 1930s when nearly all of the primary forest was harvested or burned during the "Cutover." Figure 2.14 shows the extent of Wisconsin forest in the mid-1800s based on Finley's data (Finley 1976) and remaining primary (virgin) forest in 1932. Cutover-era logging began near large rivers as early as the 1830s. During this period, trees could only be cut with axes and transported via river systems. These constraints required loggers to focus on pines because they were easier to cut and light enough to float. It was difficult to transport logs on land so logging did not expand very far from rivers. Principal logging rivers included the Wisconsin, Chippewa, Red Cedar, Black, and St. Croix and rivers in northeastern Wisconsin, including the Wolf, Peshtigo, Oconto, and Menominee (Connor 1978, Wells 1978). The areas logged first were the "pineries," which were thickly forested with large white and, less often, red pines.

It is difficult to say how much timber was removed from northern Wisconsin before the Civil War. Records indicate that some of the first buildings in Madison were made of timber cut near Wisconsin Rapids in 1837 (Wells 1978). In 1848, lumbering on the Yellow River produced 700,000 ***board feet*** in one winter. The Green Bay General Land Office estimated in 1849 that 15 million board feet were being removed annually from that region. In the same year, 37,000 logs were floated down the St. Croix River. By the late 1850s,

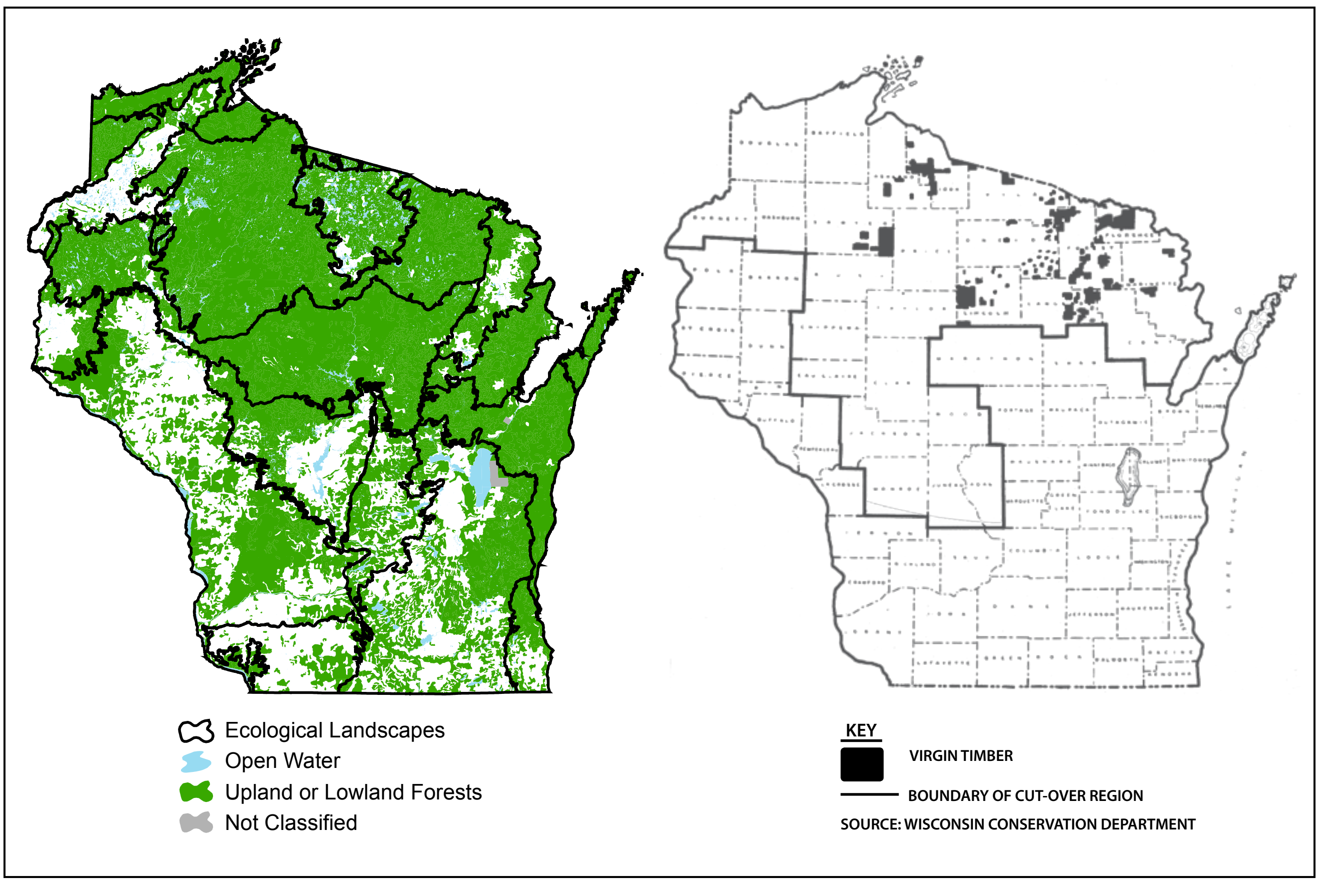

Figure 2.14. *The distribution of Wisconsin forest from Finley (1976) in the mid-1800s (left) and the remaining primary (virgin) forest in 1932 (right) (Wisconsin State Planning Board 1939).*

there were major lumber towns at Green Bay, Sheboygan, Fond du Lac, Oshkosh, Wausau, Eau Claire, Chippewa Falls, and La Crosse. There was little respect for authority during the Cutover. Of 500 million board feet of lumber shipped from eastern Wisconsin between 1844 and 1854, it is estimated that 90% was stolen from government lands.

The Civil War led to prosperity and expanded manufacturing capability in the North, which in turn led to expansion of railroads. By 1870, logging in the North Woods was changing (Wells 1978). Crosscut saws replaced axes, horses replaced the slower oxen teams, and railroads allowed logging to move inland, away from the rivers. Narrow gauge railroads were able to get into many previously inaccessible forests and allowed logs to be transported year-round. It became profitable to remove the pine component from hardwood forests, even when there were only a few large pines on an acre of land. Speculators acquired millions of acres of forest from the government, later making huge profits as the timber was liquidated. "Homesteaders" were often front men for lumber companies; they acquired quarter-sections of land in the pineries, built shacks, let the loggers take the pine, and disappeared without paying a cent to the government. The rate of cutting in the pineries increased rapidly.

Starting in the 1870s, fires began to have a major effect on the forest. Fires were often started accidentally by sparks from passing trains or were set intentionally for land clearing. When conditions were dry, as they were during the season that led up to the catastrophic ***Peshtigo Fire*** of 1871, fire spread furiously through the slash (tops and limbs) left after logging. Meanwhile, in the pineries that had been logged starting in the 1830s, white pine forests were regenerating and growing rapidly, but they did not survive. Wildfires destroyed the young pine forests and eliminated the seed sources in many places that could have provided for subsequent regeneration.

During the 1880s and 1890s, pine logging was at its peak in Wisconsin. A government report published in 1898 estimated that, of the original 130 billion board feet of pine in Wisconsin, about 17 billion remained (Roth 1898). The average cut between 1888 and 1898 was more than 3 billion board feet annually. Over 8 million of the 17 million acres of forestland in the northern counties was cut-over, largely burned over, vegetated with "waste brush," or "nearly desert." Rivers were clogged with sediment from log drives. Many were no longer ***navigable***, and their flow rate had decreased, making them less effective for producing power. Changes in drainage and soil moisture occurred because of the removal of forest cover and construction of roads and railroads, so that many wetlands became dry fields or upland forests.

By the turn of the century, pine logging was nearly finished. Lumber barons moved on to the Pacific Northwest. The companies that remained began cutting the formerly scorned hardwoods. Pulp mills were constructed to utilize the less desirable wood, beginning the gradual switch to a pulp-dominated industry. Production of ***sawtimber*** declined sharply, falling to 367 million board feet by 1935 (Wisconsin State Planning Board 1939). By 1937 more than half the employees in forest manufacturing were employed in making paper products. Efforts to sell the cutover lands to settlers were underway, often with false enticements regarding the fine quality of the soil and the beneficial climate.

During the period between about 1900 till 1930, eastern hemlock and hardwoods were removed, often by clearcutting or by high grading (Corrigan 1978). Eastern hemlock was taken for its bark, which was peeled in the woods during the spring and early summer and shipped to tanneries. The hemlock logs were generally used for lumber or pulp, although some logs were left to rot in the woods when demand was low or were used as fill beneath railroads. After a forest was harvested for hemlock bark, removal of hardwoods soon followed, often as soon as the following winter.

Railroad logging declined after the 1930s due to improvements in highways and trucks (Kaysen 1978). Selective logging began in the 1920s, and although many areas were ***high graded***, some longer-term sustained-yield management also emerged. In either case, selection cutting did not produce the immediate profit levels of clearcutting, necessitating the use of lower-cost transportation.

The paper industry had its start early in Wisconsin's history. The first mill used rags as its source material, beginning operation in Milwaukee in 1848 (McGovern 1979). Wood pulping by the groundwood method, a mechanical process, began in 1871 using spruce, aspen, and basswood. Hemlock was also used for pulp after development of the sulfite pulping method in 1887. These methods provided material for newsprint production through the 1920s. The sulfate, or ***kraft method***, was introduced in 1911, allowing pines to be used significantly. Mixed hardwoods became an important source material only after the development of semi-chemical pulping in 1948. Different species were used more heavily at various times. Records show that in 1908 aspen provided only 1% of pulpwood receipts and was not a major part of production till about 1950.

Public reaction to the abuses of the Cutover resulted in legislation and government programs designed to rehabilitate the ruined forests. Fire control programs were established by law in 1911, the same year that State nurseries began producing tree seedlings for replanting (Wisconsin State Planning Board 1939). In 1924, legislation was passed enabling the State to engage in a forest improvement program. Tax delinquency on lands where agriculture had been attempted was pervasive by the 1920s, and counties acquired many of these lands for county forests. The first land purchase for the Nicolet National Forest in northern Wisconsin took place in 1928. The ***Civilian Conservation Corps*** operated between 1933 and 1942, planting over two billion trees in cut-over areas, mostly jack pine and red pine. These events and ideas, along with natural regeneration and succession of forest species, gradually led to the forest conditions and practices of today.

Hardwoods regenerated successfully after the Cutover for numerous reasons. Deciduous tree species were better able to adapt to the intense fires that followed logging. Where intense fires had occurred and seedlings were likely burned, bare soil was quickly colonized by species with light wind-dispersed seed such as aspen and white birch (Mladenoff et al. 2008). Also, coniferous seed sources were greatly reduced by logging, fire, and farming attempts in many areas. Microclimates for seedling establishment and growth in mesic forests would also have been greatly changed following logging, favoring some species over others. In later decades, management actions have sometimes further increased the dominance of hardwoods; for example, in some areas aspen was favored at the expense of pine for use in paper-making (Steen-Adams et al. 2007). Hemlock was also selected against in some areas for decades because of its low commercial value.

Current Conditions

Although northern forest natural communities are not rare and continue to increase in overall extent, there have been major changes to their composition, structure, and function. Historical natural disturbance processes such as wind, fire, and flooding are no longer able to function in today's human-influenced landscape. Land use changes have led to homogenization in patch sizes (Mladenoff et al. 1993), reductions in patch diversity (White and Mladenoff 1994), and simplification of forest communities (loss of diversity caused by declines of some species and increased dominance by others) (Anderson and Loucks 1979, Schulte et al. 2007). Northern forests have become simplified and with reduced ecological complexity. Many of the mixed coniferous-deciduous forests have lost most of their conifers, and some species have become very difficult to regenerate. Canada yew (*Taxus canadensis*), a shrub once found in Northern Mesic Forests, has now been all but eliminated except in very small, localized areas outside of the reach of white-tailed deer.

Other issues of concern in the northern forests include fragmentation and negative edge effects (McRae 1995, Fenske and Niemi 1997, Hamady 2000, Pearson and Niemi 2000, Flaspohler et al. 2001), excessive herbivory (e.g., Wisconsin Conservation Congress 2000, Rooney and Waller 2003, Cote et al. 2004), introduction of nonnative invasive species, and declines of less-common native species (Rooney et al. 2004). Forests over 100 years in age are very rare, and FIA data show that their abundance has continually decreased statewide for the last 25 years (USFS 2010).

Many species have declined due to loss of habitat and other human impacts in Wisconsin, and the Natural Heritage Inventory program now tracks over 900 species that are state or federally listed as endangered, threatened, or special concern throughout the state (WDNR 2009). Of these, over 350 are plants. Looking only at vertebrates, there are 38 Species of Greatest Conservation Need associated with northern forest natural communities, including 23 birds, 10 mammals, and 5 herptiles (WDNR 2005). Over 200 species of rare plants have been documented in Province 212; although they are not all forest species, many occur in forested habitats.

Issues of Composition, Structure, and Function

The following are broad issues relevant to Wisconsin's northern forest communities. Additional information for northern forests in specific portions of the state can be found in the 16 ecological landscapes chapters.

Composition

Tree species richness of the northern forest communities, as a group, is similar to that found at the time of Euro-American settlement. However, the distribution and abundance of species and natural communities is now very different. Some species, such as hemlock, have declined greatly. Others, such as yellow birch and northern white-cedar, have declined less dramatically but are very difficult to regenerate. Early successional species have declined overall in recent decades, but they still cover a much larger acreage than they did at the time of the GLO public land survey (Figure 2.15). Aspen remains the second most widespread cover type in northern Wisconsin (WDNR 2010b) and the Great Lakes states overall (Cleland et al. 2001), and it is still actively maintained on large acreages. Sugar maple has greatly increased its dominance in part because of the removal, decline, or loss of competing species (e.g., eastern white pine, elm [*Ulmus* spp.], eastern hemlock, yellow birch) that were part of the hemlock-hardwood forest before Euro-American settlement. Forest management practices and herbivory have also contributed to the dominance of sugar maple.

■ **Pine-Dominated Forests (Northern Dry Forest, Northern Dry-mesic Forest).** White pine is much less common than it was prior to Euro-American settlement, and many of the former pineries are now dominated by northern red oak, red maple, and aspen (WDNR 1995). Eastern white pine is regenerating in parts of northern Wisconsin where seed sources exist and environmental conditions are favorable, such as portions of the Northern Highland Ecological Landscape, but as a forest type its acreage decreased by 17% between 1983 and 1996 (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). Suitable areas for white pine regeneration include moister sandy soils and areas where sands and morainal till soils are intermingled. South of the Tension Zone, white pine is proliferating well in many areas of the Central Sand Plains Ecological Landscape.

Although natural red pine forests are rare and are probably decreasing in extent as they age, overall, red pine acreage increased by 26% between 1983 and 1996 (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). Most stands of red pine in Wisconsin are one- to sixty-year-old plantations (WDNR 2010a). Red pine is often planted on dry and dry-mesic sites because it can produce

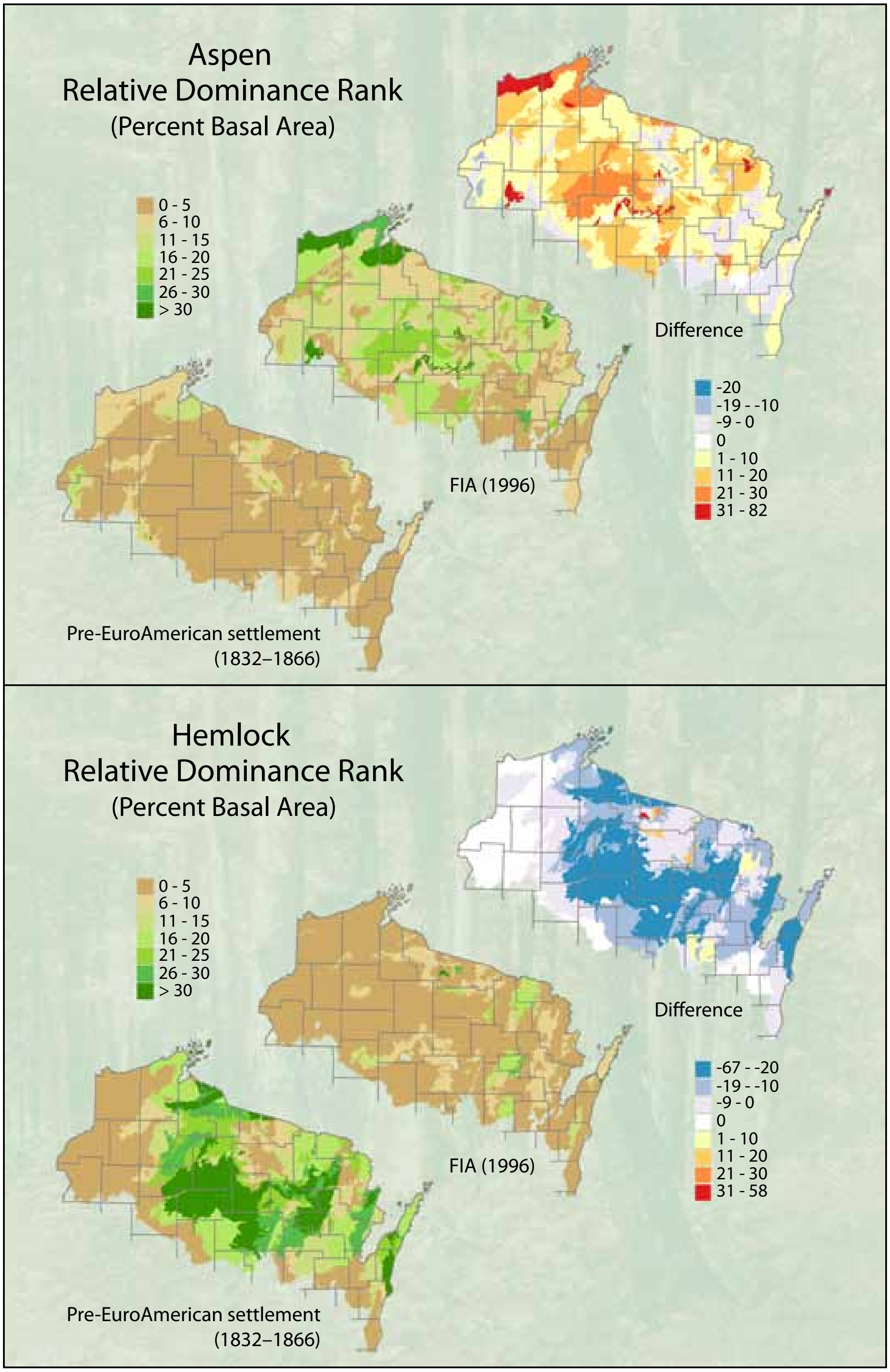

Figure 2.15. *The distribution and abundance of hemlock and quaking aspen in Wisconsin prior to Euro-American settlement. Figure courtesy of David Mladenoff, University of Wisconsin-Madison.*

well in these soils, although sometimes it replaces barrens or native dry forest communities. The Northwest Sands and Central Sand Plains Ecological Landscapes, both historically containing abundant barrens and dry forests, have the two highest red pine plantation acreages of all of the ecological landscapes (WDNR 2010a). Pine plantations are compositionally and structurally simplified and limit options for biodiversity, so the location of new plantations is an important ecological consideration.

Jack pine acreage decreased by 27% between 1983 and 1996 (Schmidt 1997, using data for Northeast, Northwest, and Central FIA Units). The decline is largely due to high mortality, salvage harvesting, and type conversion in response to extremely high jack pine budworm populations. Fire was once an important component of many jack pine forests but is now largely absent. In many areas, naturally occurring jack pine has been converted to planted red pine.

This older second-growth Northern Dry-mesic Forest is on an isthmus between two lakes and is dominated by eastern white pine and red oak. Northern Highland-American Legion State Forrest, Vilas County. Photo by Eric Epstein, Wisconsin DNR.

A dense stand of mature jack pine (Northern Dry Forest) now covers much of Long Island, a part of Apostle Islands National Lakeshore. Forests in other parts of the island are composed mostly of northern pin oak, and red pine is locally dominant. Historically, catastrophic wildfires would have renewed xeric forests such as these. Ashland County. Photo by Eric Epstein, Wisconsin DNR.

Deciduous and Mixed-Deciduous Forests (Northern Mesic Forest). The Northern Mesic Forest still covers the largest acreage of all forested community types. These forests are both ecologically and economically very important in Wisconsin. Hardwoods currently dominate the majority of these forests, although scattered, usually small, groves of pine or eastern hemlock are common in some areas. Most of these forests are in early stages of development and lack both species and structural diversity. Sugar maple is increasing its dominance likely as a result of numerous factors. It may be outcompeting conifers and other species that formerly regenerated in small gaps or on dead woody debris. Deer herbivory has also been shown to be one of the factors that gives sugar maple a competitive advantage (Anderson and Loucks 1979, Frelich and Lorimer 1985), although this can vary with location because beech can outcompete sugar maple in some areas for the same reason.

Eastern hemlock and yellow birch, once co-dominant in much of the north, are greatly reduced from levels found in the 1800s and exist in most areas as mature individual trees or small groves. Forest Inventory and Analysis data show that hemlock currently makes up about 3% of ***basal area*** in the northern forest (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). A survey of state and county forests in the mid-1990s reported that eastern hemlock-dominated forest stands made up 0.8% of the area of these lands (Eckstein 1995). Similarly, yellow birch makes up only 2.2% of the basal area in the maple-basswood forest type (USFS 2010).

Eastern white pine and, very rarely, red pine were historically an important structural element in the mesic forests of the north, often occurring as huge, ***supercanopy*** individuals several centuries old. Such structure now persists in very few places in Wisconsin.

Disease has strongly influenced species composition in Northern Mesic Forests. American elm declined 77% in volume between 1983 and 1996, due largely to Dutch elm disease (caused by the fungus *Ophiostoma ulmi*) and subsequent

Row thinned red pine stand near Woodruff. Photo by Jeff Martin.

salvage harvests and partly because of succession to sugar maple (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). Butternut canker (caused by the fungus *Sirococcus clavigignenti-juglandacearum*) affects butternut (*Juglans cinerea*) trees throughout their natural range. This disease and subsequent salvage harvests reduced butternut volume by 36% statewide between 1983 and 1996 but by only 7% in the northern forest where it was never common and reached its northern range limits (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). Emerald ash borer (*Agrilus planipennis*) has been found in numerous places in Wisconsin, and quarantine regulations were in effect in 11 counties as of this writing (early 2010). This beetle attacks all three ash species native to northern Wisconsin and will likely further limit species diversity in Northern Mesic Forests.

■ Wet Northern Forests (Northern Wet-mesic Forest, Hardwood Swamp). Northern white-cedar acreage decreased by 16% between 1983 and 1996 (Schmidt 1997, using data for Northeast, Northwest, and Central FIA Units). This species is particularly susceptible to browsing by white-tailed deer and snowshoe hare (*Lepus americanus*), and regeneration is very difficult in almost all parts of the state.

The future composition and function of most of the Hardwood Swamp natural community in Wisconsin is uncertain. American elm is now virtually absent from these forests, and black ash, often the dominant species, is at risk of being eliminated by emerald ash borer.

■ Boreal Forest. Boreal Forest now has an even more limited range than it did historically due to widespread conversion to agricultural land or to other forest types (mostly aspen), especially in its primary range on the Superior Coastal Plain Ecological Landscape. Most former Boreal Forests now lack much of their original conifer component. Climate change impacts are likely a concern for this community given its limited distribution in the state, though the proximity of the Great Lakes may mitigate possible changes to some degree.

■ Early Successional Tree Species. Aspen, which produces abundant wind-dispersed seed, was well adapted to colonize the logged and burned-over lands that were widespread in the early 1900s. By the time of the first Forest Inventory and Analysis survey in 1935, the aspen-birch forest type was found on over 4 million acres in northern Wisconsin. Of this area, 3.2 million acres were "restocking land" not yet of commercial value (data from FIA economic units 1 and 2, Cunningham and Moser 1938). Aspen forest type acreage has been reduced some in recent decades through succession, declining by 8% between 1983 and 1996 (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). Aspen is still much more abundant than it was before Euro-American settlement, and there are management goals to maintain aspen in many parts of the north.

This large northern white-cedar–dominated swamp in the Northern Highland Ecological Landscape is fed by small streams and groundwater seepage coming off of the Winegar Moraine. Toy Lake Swamp, Vilas-Iron counties. Photo by Eric Epstein, Wisconsin DNR.

Tamarack is a widespread tree in northern Wisconsin and our only deciduous conifer. It often grows with black spruce on the wettest sites that will support trees but does best under slightly less acid conditions than the bog-loving spruce. Madeline Island, Ashland County. Photo by Eric Epstein, Wisconsin DNR.

The aspen forest type, based on the 1996 FIA survey, makes up 13.5% of the land area in Province 212 (the aspen-birch forest type group makes up 15.7%), as compared with about 3.5% to 4.3% aspen and aspen-white pine forest at the time of the GLO public land survey. The extent of aspen forests younger than 40 years of age is about the same in 1996 as it was in 1983 (Spencer et al. 1988, Schmidt 1997).

White birch acreage declined by 29% between 1983 and 1996 due to succession (Schmidt 1997, using data for the Northeast, Northwest, and Central FIA Units). White birch is an early successional species that declines in the absence of fire or human-caused disturbances that expose mineral soil and is much more difficult than aspen to regenerate.

Forest Understory Composition. Historical data for understory composition are lacking relative to tree data in Wisconsin, yet certain trends are evident. A recent study resampling many of John Curtis' original sites in northern Wisconsin (Rooney et al. 2004, Wiegmann and Waller 2006) highlighted the changes to the northern forest flora over the last 50 years. In general, there have been decreases in native species and increases in exotic species. Species "winners" included many species that were already common and widespread. Species "losers" were those found to be declining in abundance, particularly those that (1) were rare historically; (2) require a specific insect species for pollination; (3) are small in stature; (4) are not able to disperse their propagules widely; or (5) are heavily browsed by white-tailed deer.

The problems associated with white-tail deer herbivory are well documented (e.g., Wisconsin Conservation Congress 2000, Rooney and Waller 2003, Cote et al. 2004), and herbivory is known to impact the understory composition of northern forests and limit the regeneration of several tree species. Many forests that might be expected to have a rich understory flora have become depauperate and dominated by Pennsylvania sedge. There appear to be relationships between strong Pennsylvania sedge dominance, heavy deer browse, abundance of nonnative earthworms, and reduced plant species diversity (Hale et al. 2006, Holdsworth et al. 2007). Canada yew has been eliminated from most forests in northern Wisconsin, largely as a result of deer browse. The loss of structure caused by deer is a detriment to wildlife that need structural features such as dense thickets of Canada yew, cedar saplings, or hemlock saplings for nest sites, foraging, or cover.

Invasive plants have a longer history of infestations in southern Wisconsin but are now becoming established in many areas in the north. Exotics such as common buckthorn (*Rhamnus cathartica*), tartarian honeysuckle (*Lonicera tatarica*), reed canary grass, and garlic mustard are just a few examples of species now invading many areas of the northern forest. These species have the potential to drastically change the composition of shrub and herbaceous layers of forests, inhibit tree regeneration, and negatively impact habitat for numerous native plants and animals.

Seedling northern white-cedar are common on this moss-covered "nurse" log, but it's unlikely that any of them will survive to the sapling stage due to either excessive browse pressure or desiccation. Chequamegon-Nicolet National Forest, Forest County. Photo by Eric Epstein, Wisconsin DNR.

In addition to browse-sensitive conifers such as hemlock, northern white-cedar, and Canada yew, some herbs may also be adversely affected by pressure from high populations of white-tailed deer. Among the potentially affected herbs are some of the forest orchids, including the Wisconsin Threatened ram's-head lady's-slipper (Cypripedium arietinum). *Photo by Thomas Meyer, Wisconsin DNR.*

Structure

Structural characteristics in northern forests have been receiving much attention in recent years. Certain structural features are lacking in many modern forests, and there are important considerations on both the stand and landscape level.

Forest Developmental Stages. Older forests in Wisconsin are rare and declining (Figure 2.16). Nearly three-quarters of the state's forests are 20–80 years old, with only 4% over 100 years old and only 1% over 120 years old, based on 2007 data (WDNR 2010b). The average age of long-lived tree species continues to increase, but the area occupied by stands more than 100 years old decreased from already low amounts between 1983 and 1996 (Spencer et al. 1988, Schmidt 1997) and further decreased between 1996 and 2010 (WDNR 2010b). Today's young forests lack many compositional, structural, and functional attributes of older forests. In addition to containing large trees, ***old forests*** typically exhibit increased structural diversity. Coarse woody debris in old-growth forests is larger, more persistent, and much more abundant (Goodburn and Lorimer 1998, Hura and Crow 2004). Wisconsin's historical old-growth forests also contained many trees with cavities and broken tops that provided nest and roost sites for wildlife. The loss of large trees, and in particular large supercanopy conifers, is a structural change from conditions before Euro-American settlement and affects wildlife habitat and ecosystem processes.

Stand-Level Structure. Many northern forest stands have a simplified structure as a result of past disturbance as well as past and current management prescriptions. As already mentioned, the majority of the forests are young, contain little coarse woody debris and cavity trees, and often exhibit declining species diversity. Large diameter trees are not maintained in many forests when they are harvested at economic maturity. The Wisconsin DNR has developed guidelines related to tree marking and retention that is designed to address some of these deficiencies during management activities. Similarly, the DNR has developed guidelines related to the harvest of woody biomass (Herrick et al. 2009) since the removal of additional woody material during these harvests further simplifies structure and impacts nutrient availability.

Forests often contain important microhabitats for rare or uncommon plants and animals including cliffs, seeps, springs, and ephemeral ponds (also known as vernal pools). Ephemeral ponds are important features for amphibian and invertebrate reproduction. Due to concerns for declining populations of some of these species, forest management guidelines often advise that equipment should avoid ephemeral ponds and that slash should not be piled in them. It has been suggested that ephemeral ponds may be less abundant in the northern forests than they were prior to Euro-American settlement due to reductions in ***pit-and-mound topography*** or changes in surface drainage patterns associated with road building. However, quantitative information on the classification, amount, and condition of ephemeral ponds in northern Wisconsin

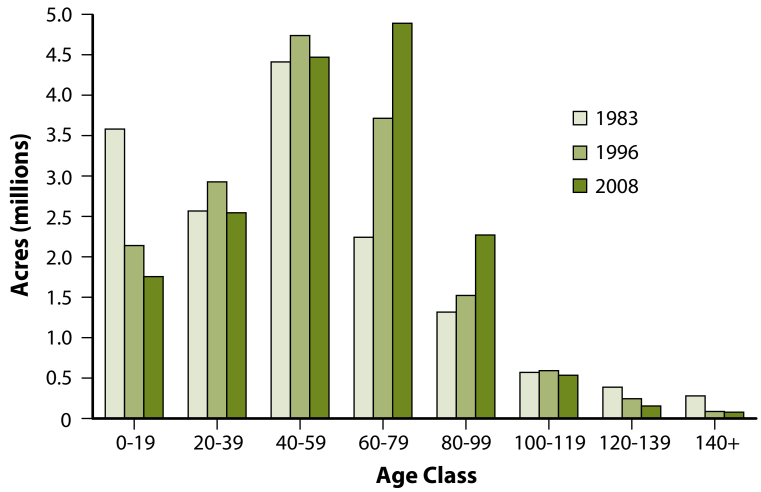

Figure 2.16. *Forest age classes from 1983, 1996, and 2008 Forest Inventory and Analysis (FIA) data (USFS 2010).*

Huge snags (eastern hemlock is depicted here, with Wisconsin DNR biologist Lisa Hartman), large living trees, and associated coarse woody debris are important and characteristic structural features that are now greatly diminished or absent from almost all northern Wisconsin forests. Old-growth forests such as this are now extremely rare anywhere in the state. Apostle Islands National Lakeshore, Ashland County. Photo by Mike Mossman, Wisconsin DNR.

is lacking. Retention of coarse woody debris can be particularly important in stands surrounding ephemeral ponds to provide habitat for amphibians. Amphibians typically travel 100 meters or more from the pool as adults, often returning to the same pool to breed (Colburn 2004).

Landscape-Level Structure. Landscape considerations are very important for northern forests. A major difference between current and past forests is the relative lack of large block, interior, and all-aged forests, especially old-growth stands. Current forest cover is a mosaic of many similar-sized stands (Mladenoff et al. 1993) with large forested patches lacking from most areas. The lack of large blocks affects species that require continuous, connected forest. Also, gap-phase disturbance that results from fine-scale wind disturbance is believed to be lacking from many second-growth northern hardwood forests. Dominant trees, most younger than those known to be common in historical forests, lack structural characteristics associated with aging that would make them more susceptible to windthrow. The lack of very small gaps can be a negative impact on certain wildlife and tree species that are more competitive in partially open forest conditions within a forested matrix. Recent research efforts are focused on trying to restore some of these features in northern forests.

Roads divide forest communities, impacting composition, structure, and functional processes. Road and housing densities have increased in northern Wisconsin in recent years (Radeloff et al. 2005, Hawbaker et al. 2006), leading to negative impacts on biodiversity and limiting the scale at which management can occur.

Large standing snags provide important foraging and breeding sites for many forest animals. In this case, a Pileated Woodpecker (Dryocopus pileatus) *has excavated the prominent deep cavities in this snag. Photo by Thomas Meyer, Wisconsin DNR.*

Black-throated Blue Warblers (Setophaga caerulescens, *listed as* Dendroica caerulescens *on the Wisconsin Natural Heritage Working List) (Wisconsin Special Concern) nest close to the ground in thickets of shrubs or saplings within large patches of older mesic forest in northern Wisconsin. Photo by Steve Maslowski.*

Red-shouldered Hawk (Buteo lineatus) *nestlings. Older stands of extensive forest in close proximity to wetlands provide suitable breeding habitat for this Wisconsin Threatened species. Photo by Gene Jacobs.*

Habitat fragmentation and edge effects are of concern in the northern forests, largely because of land use changes and cumulative and simultaneous impacts of forest management activities. Some concerns associated with fragmentation and edge are different than those found in agriculture-dominated landscapes like much of southern Wisconsin. Studies of forest neotropical migrant bird species show that in less fragmented landscapes nest predation, not Brown-headed Cowbird (*Molothrus ater*) parasitism, is the most important factor limiting nest success. More research is needed because effects vary by locale, but studies have found increased predation of certain species in proximity to forest edges (Fenske and Niemi 1997, Flaspohler et al. 2001). Changes in interspecific competition are a related issue, and impacts on forest specialist bird species have been found in forest openings (Hamady 2000). Landscape composition, including the relative dominance of forested and nonforested patches and the inclusion of coniferous components, appears to play roles in habitat selection. Some forest specialists will occupy less-preferred habitats if the surrounding area has desirable attributes or components (McRae 1995, Pearson and Niemi 2000).

The Golden-winged Warbler (Vermivora chrysoptera) *has suffered population declines over much of its range in recent decades. Good numbers still occur in parts of northern and central Wisconsin, where it breeds in dense thickets of deciduous shrubs and saplings including young stands of quaking aspen. Photo by Brian Collins.*

Structurally complex old-growth forests such as the stand depicted were once common across much of northern Wisconsin but are now very rare. This stand has a supercanopy of huge white pine and a canopy composed mostly of large hemlock, yellow birch, and sugar maple. Boggy peatlands and several small softwater lakes occur within this complex. Vilas County. Photo by Eric Epstein, Wisconsin DNR.

The ongoing process of residential and commercial development has led to habitat loss, permanent fragmentation, and changes in landscape composition, structure, and function. Other consequences of a human population in the forest include predation of native wildlife by cats and dogs, incursions of generalist species like raccoon (*Procyon lotor*) and skunk (*Mephitis mephitis*), and wildlife baiting and feeding, which can add to already high deer numbers.

Clearcutting aspen has kept significant acreages in an early succession stage, reducing both vertical and horizontal diversity. The total amount and also the spatial dispersion of aspen is an issue because of the creation of large amounts of edge and habitat fragmentation.

Function

As with other community groups, the ability of northern forest ecosystems to function is impacted by many biotic and abiotic factors. Some of the major issues are presented here.

■ **Contemporary Natural Disturbances.** The major disturbances in the northern forests are quite different from the past. Although natural disturbances caused by weather events such as tornadoes and other severe storms still cause tremendous changes to these systems, many of the most challenging natural disturbances are relatively new in Wisconsin. Excessive herbivory (by white-tailed deer, sometimes snowshoe hare,

Commercial timber harvest is now the most common disturbance affecting the forests of northern Wisconsin, especially on public lands. Photo by Paul Pingrey.

and livestock in parts of the north where grazing occurs) is impacting the reproductive potential of several key tree species as well as certain understory plants and leading to community simplification (Anderson and Loucks 1979, Frelich 1995, Cote et al. 2004, Rooney et al. 2004). While herbivory does not have the dramatic visual impacts observed with windstorms, this chronic low-level disturbance can be just as ecologically devastating or even more devastating over the long term.

Invasive species are spreading, and some are expected to increase in much of the north. Invasive forest diseases, insects, and plants are an increasing problem due to the continual introduction of nonnative species. Oak wilt (caused by the fungus *Ceratocystis fagacearum*) is damaging northern red, black, and northern pin oak in the southern portion of the northern forest. Gypsy moth (*Lymantria dispar*) populations are gaining ground in some northern forests. Jack pine budworm outbreaks resulted in extensive mortality and salvage harvesting over the past decade. Beech bark disease is the result of an interaction between a nonative insect (a scale) (*Cryptococcus fagisuga*) and fungi (*Neonectria* spp.) and does not occur if either is absent.Beech bark disease has been detected in Door County and threatens beech wherever it occurs in the state. Hemlock woolly adelgid (*Adelges tsugae*), a nonnative aphid-like insect, is a future concern; it has severely impacted eastern hemlock in the eastern portion of its range. New invasive plants continue to increase and spread, sometimes outcompeting and replacing native species and leading to negative impacts. Several species of exotic earthworms are invading northern temperate forests and can dramatically alter ecosystem composition, structure, and function (Hale 2007, Holdsworth et al. 2007). Worm-invaded forests can have reduced forest floor (duff layer) thickness, increased ***soil bulk density***, and significantly reduced plant species richness and abundance.

The recent subdivision of large private holdings has resulted in many small ownerships, and the construction of homes, roads, and other infrastructure throughout areas of formerly contiguous forest. Management options are severely limited under such scenarios. Oneida County. Photo by Eric Epstein, Wisconsin DNR.

Human Impacts to Function. Numerous changes to ecosystem function in the north are a result of human actions; some are direct, and many are indirect. Below are some examples of these impacts in northern forests:

- Forest management over most of the landscape responds to social goals that emphasize utilitarian and efficient production of timber resources that focuses on a limited suite of species and the vigorous growth and harvest of young forests.
- Wildfire suppression continues, reducing its role as a primary natural disturbance factor in the pine forests. Fire fuel-load is growing in some areas because of fire suppression, which could lead to more severe fires in the future.
- Relatively young forests are less susceptible to windthrow disturbance, resulting in fewer forest gaps and a lack of trees with broken limbs and tops. The lack of these features can negatively affect some wildlife populations.
- Damaged riparian forests allow banks to erode and sediment inputs to increase in streams and lakes. Lack of large trees along shorelines limits recruitment of large woody debris into lakes and streams. Voluntary ***best management practices*** may reduce some of these impacts.
- Soil compaction can occur from the passage of heavy equipment, particularly on moist loamy soils, resulting in slower growth or poor regeneration of some tree species.
- Pollution has not been recognized as a large impact in most of the northern forest. However, ground-level ozone could impact sensitive tree species like aspen and white pine in areas near the Fox Valley in eastern Wisconsin. Also, nitrate leaching in excess of precipitation inputs has been documented for several forested sites in northern Wisconsin (Bockheim and Crowley 2002).
- Climate change could drastically affect northern forests, allowing oak-dominated forests to move north and the remaining examples of the Boreal Forest community to be lost in Wisconsin. Many wetland forests could also change to drier forest types.
- Only 18% of commercial timber sales on lands in private, nonindustrial ownership benefit from professional forestry assistance. High-grade logging continues on a significant acreage of private forestland (WDNR 1999).

Land Use and Environmental Considerations

Land uses can have some of the most dramatic impacts to ecosystems. Although the northern forest is more intact than most places south of the Tension Zone, there are many issues that are becoming increasingly important.

- Primary home, second home, and commercial development are growing and encroaching on forestlands and riparian zones.

- Tourism in the north is increasing, especially in counties with many lakes and along the Great Lakes. This can have numerous negative ecological impacts.
- Off-road vehicle use has increased in recent decades, and demand for this form of motorized recreation continues to increase. Combining motorized and nonmotorized recreation in the same area leads to conflicts among recreational users. Environmental impacts of off-road vehicle use have been observed but are not well documented.
- Northern lakes are extremely important resources in Wisconsin, both biologically and for the socioeconomic benefits they provide. However, many lakes of all sizes now have developed shorelines. Between the 1960s and the mid-1990s, alone, about two-thirds of the undeveloped lakes 10 acres and larger had one or more dwellings built on their shores (WDNR 1996).
- Designated wilderness areas are of small extent compared to the large acreages located in Michigan and Minnesota.

Statewide Ecological Opportunities for Northern Forest Communities

There are many opportunities to apply ecological principles to northern forest planning and management. The opportunities described below are intended to consider all characteristic forest successional stages, age classes, and patch sizes and distributions at landscape and regional scales. The goal is to implement ecosystem management in northern forest communities by emulating the natural variability of composition, structure, and function across Wisconsin's northern forest communities. Chapters 1 and 6 of this book describe principles of ecosystem management and important socioeconomic considerations and trade-offs, many of which would play a role in implementing these opportunities.

Forest Composition Opportunities

As noted previously, several important tree species are declining in the northern forests. The species described here are declining because regeneration has become challenging for various reasons. Climate may further impact our ability to maintain some of these and other species in the future.

- Northern white-cedar (all ecological landscapes corresponding to Province 212): Research is needed to learn more about requirements for regenerating this species, although reduction of deer populations or other ways to mitigate herbivory will almost certainly be necessary.
- Eastern hemlock (wherever it is still present): As with northern white-cedar, more information is needed on how to regenerate this species. Maintain and promote eastern hemlock wherever possible. Formerly widespread and abundant in much of the north, it is now reduced or absent from many appropriate locations.

Protection and management of northern forest communities also lends itself to the protection of embedded waterbodies and wetlands in much of northern Wisconsin. This stream is bordered by a corridor of lowland hardwood forest (silver maple and ash). The small lake is surrounded by marsh, sedge meadow, and shrub swamp communities. The heavily forested uplands are presently dominated by quaking aspen (the bright yellow), but boreal conifers such as spruce and fir are well represented in the draws and throughout the forest understory. The red clay soils are highly erodible unless managed very carefully. In addition, the area pictured is part of an undeveloped corridor that runs from Lake Superior into the extensive forests of Minnesota and northwestern Wisconsin. Nemadji River, Douglas County. Photo by Eric Epstein, Wisconsin DNR.

This aerial photo of a portion of the Northern Highland American Legion State Forest shows an example of a relatively large and undeveloped site that offers opportunities to protect undeveloped lakes and wetlands, restore white pine and red oak as dominant members of the forest canopy, provide for patches of old-growth forest, and maintain an extensive matrix of working forest. In addition, a number of rare forest plants and animals have been documented here. An integrated approach to planning is needed to take advantage of the management opportunities presented at this site. Vilas County. Photo by Eric Epstein, Wisconsin DNR.

- Jack pine (Northwest Sands, Northeast Sands, and Central Sand Plains Ecological Landscapes): Jack pine acreage continues to decline in the state. Suitable areas for jack pine are of limited extent in Wisconsin, so additional work is needed to identify the best areas and encourage jack pine reproduction and management there. At some locations, management of Pine Barrens and jack pine-dominated xeric forests may be compatible and offer increased flexibility to planners and managers (e.g., see the "Conservation Design" section in Chapter 1).
- White spruce, balsam fir, and eastern white pine in Boreal Forest communities (Superior Coastal Plain Ecological Landscape): Although geographically limited in Wisconsin, the Boreal Forest is an important and biologically distinctive community type. Locating stands in which to increase conifer representation is an important opportunity in the Superior Coastal Plain because most stands are now predominately aspen with simplified composition and structure. Relationships with "boreal forests" farther north and east should be clarified because Wisconsin's examples of the Boreal Forest community occur mostly on the heavy red clay deposits along Lake Superior and have other unusual attributes. Stands on dolomite bedrock on the northeastern Door Peninsula need protection from excessive deer browse and increased residential development and associated habitat fragmentation.
- White birch (all ecological landscapes): White birch was and will be a minor forest component, but some places, such as open shorelines or areas where fire might be used to improve seedbed and germination conditions, may offer good opportunities to maintain a white birch component.

Landscape-Scale Planning Opportunities

Landscape-scale considerations can be incorporated into planning efforts, regardless of the size of the property or group of properties involved. The following are important issues to discuss during planning, including the development of Wisconsin DNR master plans.

- Designate and increase acreage of old-growth communities in various natural community types and all ecological landscapes, where appropriate. Several types are especially important due to past extent and current scarcity, including hemlock-hardwoods, northern hardwoods, and red and white pines.
- Look for opportunities to maintain hydrologically intact forested wetlands.
- Determine the appropriate acreage and distribution pattern of aspen, looking for the best places to maintain areas of early successional forest while providing sufficient areas to maintain other types that may not be compatible with aspen management.
- Evaluate opportunities to convert idle agricultural lands in all ecological landscapes to native cover types. Some areas may be appropriate for reforestation (e.g., portions of the Forest Transition Ecological Landscape), but it will be important to consider needs for open habitats in other areas.
- Maintain and enhance habitats for threatened and endangered plants and animals whenever and wherever feasible (all ecological landscapes).
- Continue to retain representative natural communities. Seek tax incentives for landowners who wish to restore or maintain natural communities and High Conservation Value Forests (all ecological landscapes).
- Maintain existing large patches of forest and reconnect isolated forest patches wherever possible to reduce the negative effects of habitat fragmentation (all ecological landscapes).
- Restore or maintain forest habitats in important river corridors that connect, or could connect, key sites (e.g., large public lands) within ecological landscapes and/or that cross ecological landscape boundaries (including the Tension Zone).
- Decrease practices that enhance white-tailed deer habitat such as maintaining permanent wildlife openings and feeding where this conflicts with other management goals, such as maintaining browse sensitive vegetation.
- Conduct comprehensive biological inventories to assist planning efforts, especially at large scales, as data are lacking for many areas.

Forest Management Opportunities

These opportunities are related directly to management of northern forests for restoration and/or to provide additional ecological benefits:

The northern forests are home to many of Wisconsin's most iconic species, including the Common Loon (Gavia immer) *(pictured here), Bald Eagle* (Haliaeetus leucocephalus), *Osprey* (Pandion haliaetus), *gray wolf, black bear, and bobcat. Photo courtesy of U.S. Fish and Wildlife Service.*

- Enhance structural diversity within managed stands. Include a component of large trees, including conifers where possible, to provide structural diversity. Retain large diameter cavity trees and coarse woody debris by retaining some fallen logs after harvest and allowing some trees to reach their natural lifespan.
- Manage to maintain a component of eastern hemlock, yellow birch, black cherry, and white ash in northern hardwood forests where they are no longer present or have been greatly reduced and identify and encourage development of eastern white pine in various community types, including some mesic sites, where possible.
- Increase representation of old-growth forests by allowing some forests to reach biological maturity and beyond, especially on very rich sites where older age-classes are presently lacking.
- Lengthen rotations of long-lived species to add missing age and structural diversity and explore the use of extended rotations of short-lived species to add structural diversity in the short term (all ecological landscapes). There are many opportunities in the north for "managed old growth" where some trees are harvested and others are grown beyond economic rotation age to provide for some of the characteristics associated with old growth. While these areas would provide major ecological benefits, designating benchmark areas for which to develop old-growth forests through passive methods will also be important.
- Close roads (with gates, berms, or similar structures) following timber sales to minimize impacts of off-road vehicles (all ecological landscapes). Reusing logging roads during future harvests can help reduce soil compaction. Do not seed roadbeds with aggressive nonnative species; favor native plants or allow the area to revegetate naturally.
- Maintain the condition of woods roads and trails kept permanently open to reduce soil and water impacts.
- Promote species and structural diversity when establishing and thinning plantations (in all ecological landscapes).
- Evaluate the potential and effectiveness of identifying areas where high volumes of wood can be produced in plantations in lieu of harvesting sensitive areas. Clear agreements would be needed to ensure that the offset in harvesting takes place. This strategy would not provide for all habitats' needs but might provide an additional tool along with others mentioned.
- Emulate some of the patchiness and variability of natural fire and wind disturbance regimes in suitable forest communities and appropriate ecological landscapes. This could involve leaving a green tree component in clearcuts or using group selection harvests to create patch openings in sizes similar to natural disturbances.
- Consider scale and context in making decisions on retention and restoration.

Statewide Forest Opportunities

These opportunities are related to statewide policies or guidelines that pertain to the northern forests as well as other communities throughout the state:

- Reduce negative impacts of herbivory on sensitive species (all ecological landscapes) by managing white-tailed deer populations at or below established goals wherever possible.
- Evaluate opportunities to use landscape planning of cover types and timing of management practices to reduce deer numbers in select areas while maintaining higher deer numbers in others. Evaluate possibilities to maintain special management areas on public lands where regeneration of browse-sensitive species is a focus.
- Continue to document the adverse impacts of off-road vehicles and develop ability to mitigate these impacts, especially near sensitive areas. At least one study has already demonstrated the potential for invasive plants to be spread by ATVs (Rooney 2005). Since vehicle tires are presumed to be a method of earthworm spread via cocoons (egg cases), this is likely another concern regarding ATV use in northern forests.
- Prevent and control the spread of invasive nonnative species to the extent possible; prioritize and monitor the species of greatest potential threat (all ecological landscapes). Preventing the spread of invasive species to currently uninfested areas, especially those with high conservation value, is a major ecological priority for all of Wisconsin.
- Restore degraded riparian zones (all ecological landscapes).
- Continue to implement and encourage the use of best management practices to protect water resources.
- Develop guidelines for protection and management of Ephemeral Ponds (all ecological landscapes).

Ecological Opportunities by Ecological Landscape

The best opportunities for preservation, enhancement, and restoration of northern forest communities can be found in all of the ecological landscapes in northern Wisconsin:

- North Central Forest
- Northern Highland
- Northeast Sands
- Northern Lake Michigan Coastal
- Northwest Sands
- Northwest Lowlands
- Superior Coastal Plain
- Forest Transition

New Findings, Opportunities, and Conservation Needs

- Ongoing research projects in Wisconsin through the University of Wisconsin-Madison and the Wisconsin DNR should provide useful information regarding the use of management techniques to restore structural characteristics associated with old-growth forests.
- Fire is seldom used now as a forest management tool in Wisconsin due to logistical challenges and considerations. Fire has been used in several surrounding states as a tool in forested ecosystems, and there is potential for its use in managing certain forest types here.
- Overcoming forest homogenization and simplification is an ongoing challenge for Wisconsin forests (WDNR 2010b, Schulte et al. 2007).
- There are several forest pests that threaten northern forests. Climate change may facilitate attacks by additional pests, such as the hemlock wooly adelgid.
- Deer herbivory continues to be a major threat to northern forest ecosystems, and deer population levels continue to be a very controversial topic in Wisconsin and other states.
- Invasive species threaten the northern forests. Many of the invasive plants that are already widespread in the south are being seen with increasing frequency in the northern part of the state.
- Retaining biological legacies (large living and dead trees and cavity trees) is an important consideration for timber management in the north. Recent updates to the Wisconsin DNR's *Silviculture and Forest Aesthetics Handbook* contain guidelines for retaining green trees, cavity trees, and coarse woody debris (WDNR 2013).
- Ephemeral Ponds are important components of some northern forests. Although these natural communities are partially protected by Wisconsin's Best Management Practices for Water Quality, guidance is minimal, and Wisconsin lacks specific guidelines for managing them as communities or habitats. The importance of these communities has been recognized nationally, and several states in the northeastern U.S. now have management guidelines for these features as well as educational materials related to the identification and ecology of Ephemeral Ponds. There is a need for more information in Wisconsin including help in classifying and identifying the importance of these areas. One important question is how to identify the most ecologically important ponds in the few areas of the state with large concentrations of them. In addition, it will be important to consider the forests surrounding the Ephemeral Ponds when developing management plans because they provide habitat for pond-associated animal species for much of the year.
- Sale of large industrial forest tracts that have been split into smaller parcels is a concern that has ecological implications as well as implications for forest management. Recent large "forest legacy easements" have been established as a tool to help with this issue, but it is too early to know how well these areas will function ecologically.
- There is likely to be increased pressure for use of northern forests for multiple uses. It may become challenging for state lands to meet all of the desired needs and expectations for resource extraction, recreation, and other uses.
- The use of woody biofuels could have potentially significant impacts in northern forests on both public and private lands. The Wisconsin DNR recently completed guidelines for the harvest of woody biomass (Herrick et al. 2009). There will be a need to monitor and update these guidelines as we learn more, particularly if the use of woody biomass significantly increases in the future.

Scientific names of species mentioned in the northern forest communities assessment.

Common name	Scientific name
American basswood	*Tilia americana*
American beaver	*Castor canadensis*
American beech	*Fagus grandifolia*
American elm	*Ulmus americana*
Bald Eagle[a]	*Haliaeetus leucocephalus*
Balsam fir	*Abies balsamea*
Beech bark disease fungi	*Neonectria* spp.
Beech bark disease scale insect	*Cryptococcus fagisuga*
Big-tooth aspen	*Populus grandidentata*
Black ash	*Fraxinus nigra*
Black bear	*Ursus americanus*
Black cherry	*Prunus serotina*
Black oak	*Quercus velutina*
Black spruce	*Picea mariana*
Black-throated Blue Warbler	*Setophaga caerulescens,* listed as *Dendroica caerulescens* on the Wisconsin Natural Heritage Working List
Bobcat	*Lynx rufus*
Brown-headed Cowbird	*Molothrus ater*
Bur oak	*Quercus macrocarpa*
Butternut	*Juglans cinerea*
Butternut canker fungus	*Sirococcus clavigignenti-juglandacearum*
Canada yew	*Taxus canadensis*
Common buckthorn	*Rhamnus cathartica*
Common Loon	*Gavia immer*
Dutch elm disease fungus	*Ophiostoma ulmi*
Eastern hemlock	*Tsuga canadensis*
Eastern white pine	*Pinus strobus*
Elk	*Cervus elaphus*
Elm	*Ulmus* spp.
Emerald ash borer	*Agrilus planipennis*
Fisher	*Martes pennanti*
Garlic mustard	*Alliaria petiolata*
Golden-winged Warbler	*Vermivora chrysoptera*
Gray wolf	*Canis lupus*
Green ash	*Fraxinus pennsylvanica*
Gypsy moth	*Lymantria dispar*
Hemlock woolly adelgid	*Adelges tsugae*
Hickory	*Carya* spp.
Hill's (northern pin) oak	*Quercus ellipsoidalis*
Jack pine	*Pinus banksiana*
Jack pine budworm	*Choristoneura pinus*
Northern Goshawk	*Accipiter gentilis*
Northern red oak	*Quercus rubra*
Northern white-cedar	*Thuja occidentalis*
Oak wilt fungus	*Ceratocystis fagacearum*
Osprey	*Pandion haliaetus*
Pennsylvania sedge	*Carex pensylvanica*
Pileated Woodpecker	*Dryocopus pileatus*
Quaking aspen	*Populus tremuloides*
Raccoon	*Procyon lotor*
Ram's-head lady's-slipper	*Cypripedium arietinum*
Red maple	*Acer rubrum*
Red pine	*Pinus resinosa*
Red-shouldered Hawk	*Buteo lineatus*
Reed canary grass	*Phalaris arundinacea*
Silver maple	*Acer saccharinum*

Continued on next page

Scientific names of species, continued.

Common name	Scientific name
Snowshoe hare	*Lepus americanus*
Spruce budworm	*Choristoneura fumiferana*
Spruce Grouse	*Falcipennis canadensis*
Skunk	*Mephitis mephitis*
Sugar maple	*Acer saccharum*
Tamarack	*Larix laricina*
Tartarian honeysuckle	*Lonicera tatarica*
White ash	*Fraxinus americana*
White birch	*Betula papyrifera*
White oak	*Quercus alba*
White spruce	*Picea glauca*
White-tailed deer	*Odocoileus virginianus*
Yellow birch	*Betula alleghaniensis*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologist Union.

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Southern Forest Communities

Community Description

Wisconsin's southern forest communities cover an area of approximately 5.4 million acres, based on the forested acreage in Province 222 (USFS 2010). This Province includes the areas south and west of the Tension Zone (Figure 2.17), where the majority of the southern forest community types occur. However, there are notable areas where southern and northern forest types intermingle and may be difficult to differentiate.

Current Vegetation

This section describes the current range of major forest cover types in southern Wisconsin and their associated shrub and herbaceous vegetation. Southern forests are often characterized using cover types that can be derived from Forest Inventory and Analysis (FIA) data. One issue of particular importance for the southern forests is that forest types summarized from FIA data are for "timberland," which includes anything with at least 17% tree cover and could also include current and former savanna communities. The FIA estimates for cover provided here are based on 2008 data (USFS 2010). Figure 2.18 provides the relative abundance of each cover type in southern Wisconsin. Forest understory vegetation is not characterized by Forest Inventory and Analysis, so additional sources have been used to describe these vegetative components, including Curtis (1959), Kotar and Burger (1996), and Wisconsin DNR Bureau of Endangered Resources statewide inventory files. Plant nomenclature follows Voss (1972, 1985, 1996) and Mickel (1979).

The majority of the forests in Province 222 are characterized by broadleaf deciduous tree species, and there are relatively few areas with conifers outside of plantations. About 32 native tree species can be found in the southern forest; their distribution is a function of environmental characteristics and past disturbance.

Oak-hickory is the most common forest type group in Province 222, occupying about 16% (2.7 million acres) of the land area. This type is most prevalent throughout the Western Coulees and Ridges Ecological Landscape. Oak-hickory is also common in the Central Sand Hills, Central Sand Plains, and in the Kettle Moraine region of the eastern Southeast Glacial Plains Ecological Landscape. This community group includes red oak, white oak, black oak, bur oak and shagbark hickory, often with components of red maple, aspens (*Populus tremuloides* and *P. grandidentata*), American basswood, white birch, white pine, or black cherry. Oaks dominate the composition in a majority of the oak-hickory stands, although red and sugar maples, red elm (*Ulmus rubra*), white ash, and black cherry are increasing in abundance due to the greatly diminished frequency of fire, their greater tolerance to shade, and ability to sprout vigorously after logging disturbances. These species also tend to exhibit rapid growth rates and are less palatable to white-tailed deer and cattle than seedling and sapling oaks (Alverson et al. 1994).

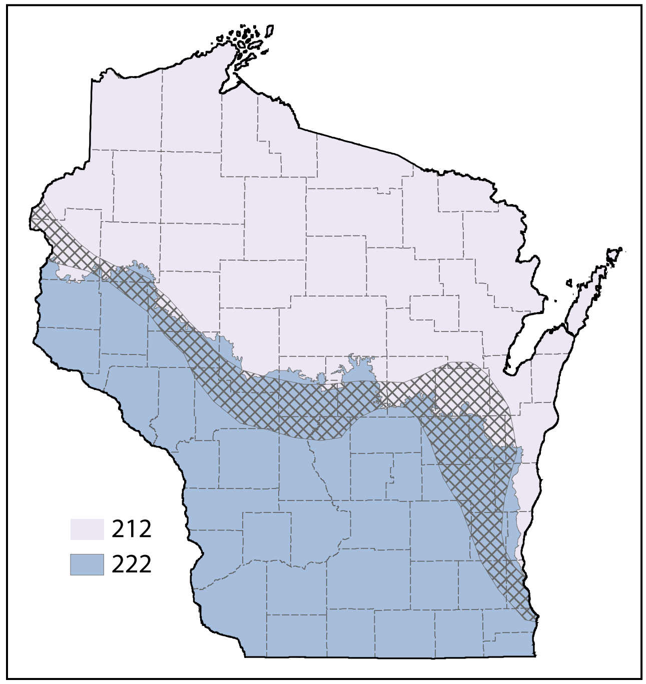


Figure 2.17. *Location of Provinces in Wisconsin (Cleland et al. 1997), along with estimated location of the Tension Zone (crosshatched), adapted from Curtis (1959).*

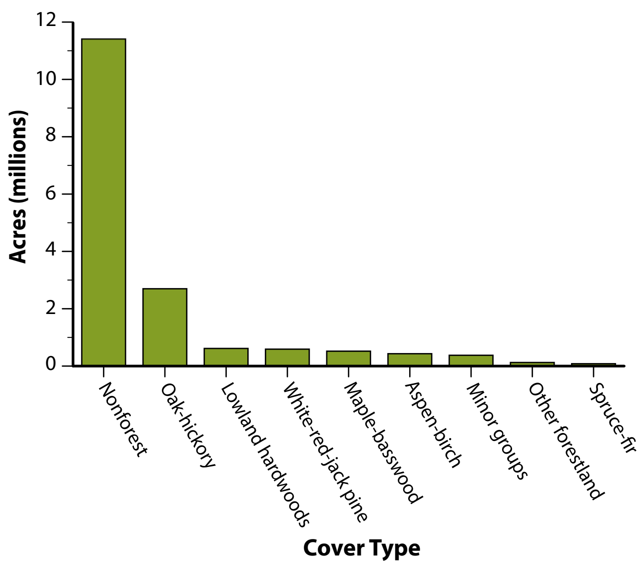


Figure 2.18. *Major forest cover types in Province 222 from Forest Inventory and Analysis (FIA) data (USFS 2010).*

The oak-hickory group is similar to the Southern Dry-mesic Forest and Southern Dry Forest natural community types. Characteristic understory species on dry and dry-mesic sites include shrubs such as hazelnut (*Corylus americana*) and gray dogwood (*Cornus racemosa*) and the low twining hog-peanut (*Amphicarpaea bracteata*) as well as herbs such as false Solomon's seal (*Smilacina racemosa*), lopseed (*Phryma leptostachya*), tick-trefoils (especially *Desmodium glutinosum* and *D. nudiflorum*), and enchanter's nightshade (*Circaea lutetiana*). Lady fern (*Athyrium filix-femina*) and interrupted fern (*Osmunda claytoniana*) are often present and sometimes abundant in dry-mesic oak forests. The prevalence of woody shrubs as well as the saplings of shade tolerant but fire-sensitive trees (e.g., maples) is likely due at least in part to the exclusion of fire from the southern landscape. Lack of fire has also resulted in changes to the herbaceous component of the oak forests. Light-demanding plants, mostly summer- and fall-blooming species, were very prevalent in southern oak woods 50 or more years ago (Curtis 1959). Now they have become far less common and are often restricted to edges, trails, and large canopy gaps. These light-demanding species include grasses, sedges, legumes, figworts, mints, parsleys, and a wide variety of composites, including asters, goldenrods, sunflowers, and others (Rogers et al. 2008, 2009).

Mature forest dominated by large red and white oaks. Note the absence of mesophytic competitors in the stand pictured. Maintaining oaks on mesic and dry-mesic sites in the absence of fire and in the presence of dense growths of shrubs and saplings has been problematic. Driftless Area, Sauk County. Photo by Eric Epstein, Wisconsin DNR.

Lowland hardwood forests cover approximately 4% (615,000 acres) of the land area of Province 222. Important canopy species include silver maple, red maple, green ash (*Fraxinus pennsylvanica* var. *subintegerrima*), swamp white oak, river birch (*Betula nigra*), cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), and black willow (*Salix nigra*). Several lowland trees with ranges centered in the southern U.S., such as sycamore (*Platanus occidentalis*), honey locust (*Gleditsia triancanthos*), and Kentucky coffee tree (*Gymnocladus dioicus*), can be found locally in bottomlands along the major river systems in extreme southern Wisconsin. American elm was formerly an important member of the lowland hardwood forests, but Dutch elm disease has devastated its populations throughout the species' range. Young elm is still relatively common in lowland forests but seldom reaches the canopy before succumbing to Dutch elm disease.

Though all lowland hardwood forests are subject to periodic episodes of high water, becoming either saturated or flooded, there are distinct functional differences between forests on river floodplains and those in isolated lowland basins (Dunn 1987). These distinct forest types correspond to the Floodplain Forest and Southern Hardwood Swamp natural community types. Floodplain Forests are subject to scouring effects (water, ice, and debris), sediment deposition, and periods of saturation or inundation interspersed with very dry conditions. Vegetative composition, including successional patterns, can vary depending on the timing and severity of flooding. On many rivers and streams, flood regimes have been significantly affected by dam construction, wetland drainage, channelization, road construction, and urban development. Other factors that have affected this forest type include logging, grazing, ditching, and colonization by invasive plants. Southern Hardwood Swamps are found in closed (insular) depressions and may be subject to prolonged periods of saturation or inundation by standing, rather than moving, water—especially in the

Extensive lowland hardwood forests occur within the floodplains of southern Wisconsin's larger rivers. Silver maple, swamp white oak, and green ash form the canopy of the forest pictured here along the lower Wolf River. Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

spring or after major precipitation events. These hydrologic differences lead to understory composition and growth rates that are distinctly different from those of floodplains. Southern Hardwood Swamp is an extremely localized community type, and it comprises a very small portion of Province 222 relative to Floodplain Forest.

Floodplain Forest of silver maple, green ash, river birch, and hackberry in winter. Lemonweir River, near its confluence with the Wisconsin River. Juneau County. Photo by Eric Epstein, Wisconsin DNR.

The cardinal flower is a showy and characteristic understory plant of southern Wisconsin's Floodplain Forests. Photo by Drew Feldkirchner, Wisconsin DNR.

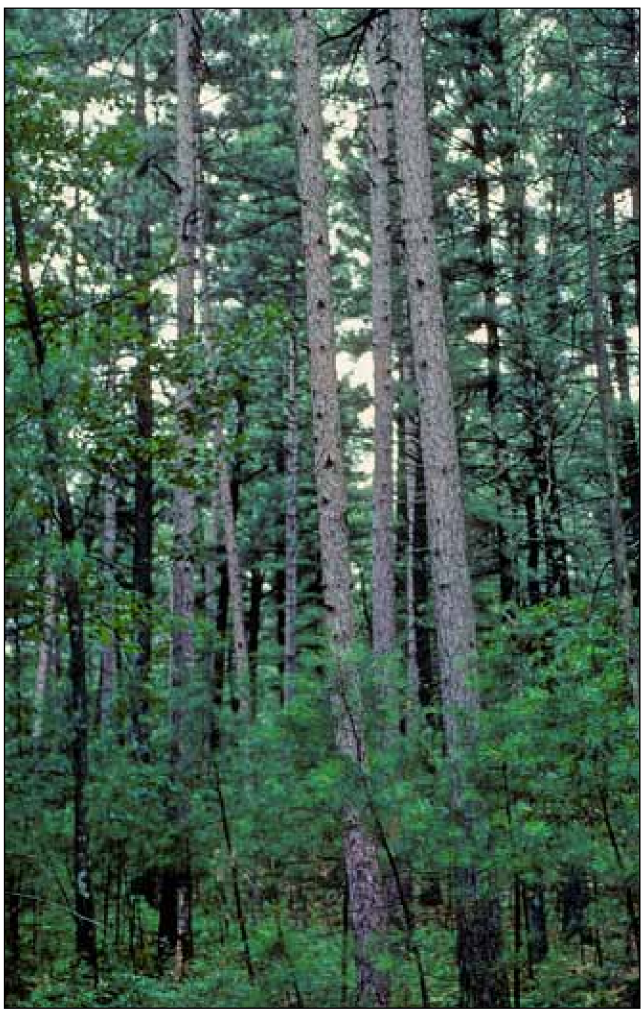
Common understory plants of the lowland hardwood forests often occur in a patchy distribution. They include wood nettle (*Laportea canadensis*), sedges, grasses, touch-me-not (*Impatiens biflora*), cardinal flower (*Lobelia cardinalis*), green dragon (*Arisaema dracontium*), green-headed coneflower (*Rudbeckia laciniata*), and buttonbush (*Cephalanthus occidentalis*). Vines are often prominent in Floodplain Forests, particularly wild grape (*Vitis riparia*), woodbine (*Parthenocissus vitacea*), poison ivy (*Toxicodendron radicans*), moonseed (*Menispermum canadense*), and wild cucumber (*Echinocystis lobata*) (Curtis 1959).

Forests of red pine, eastern white pine, and/or jack pine occur on 4% (590,000 acres) of the land area of Province 222. The greatest acreages of pine forests occur mostly in the sandy areas of central Wisconsin, in the Central Sand Plains and Central Sand Hills Ecological Landscapes. The "Current Land Cover" maps in the individual ecological landscape chapters show the relative prevalence of conifers in these ecological landscapes. Monotypic red pine plantations make up a substantial portion of the southern Wisconsin pine forests today. Red pine forests occupy about 245,000 acres of southern Wisconsin, of which about 90% are plantations (WDNR 2010). Much of southern Wisconsin is south of the natural range for red pine, and plantations established outside of the natural geographic range often decline at young ages. This situation may be exacerbated in the future due to climate change. Eastern white pine is becoming increasingly abundant in some of the forests (including both hardwood and pine stands) of the Central Sand Plains and Central Sand Hills Ecological Landscapes, and this species is likely to increase in dominance in these landscapes over time because of its longevity, stature, and greater tolerance to shading than the other native pines.

Natural pine forests in southern Wisconsin may bear strong similarities to the pine forests found farther north and most closely correspond to northern community types. Characteristic understory species often include blueberries (*Vaccinium angustifolium* and *V. myrtilloides*), wintergreen (*Gaultheria procumbens*), pipsissewa (*Chimaphila umbellata*), and bracken fern. Understory differences between northern and southern pine forests include herbs found in southern pine forests that are usually associated with the dry hardwood forests of the south; understory species of southern pine forests can also include a few species more often found in savannas or even dry prairies. Southern pine forests may also contain oaks with predominately southern distributions in Wisconsin, such as the black, white, and bur oaks.

In the Western Coulees and Ridges and Southwest Savanna Ecological Landscapes, the pine forests tend to be small and isolated, may lack characteristic "northern" understory plants, and are often found within a landscape matrix that contains more agricultural and residential land than is typical of areas farther north. Common sites for these southern Pine Relicts are dry, rocky bluffs, which may support small, xeric stands of white, red, or jack pine or, more rarely, mixtures of all three native pine species. White pine is more widely distributed than the other conifers, occurring as a component of both dry and dry-mesic forests at a number of locations. It is an important canopy species in forests on older glacial materials deposited prior to the Wisconsin glaciation, in areas that include Dunn, Pierce, and St. Croix counties. In rare instances, white pine was also an important canopy component of forests on mesic sites. The best examples formerly occurred in the upper Kickapoo River drainage in eastern Vernon and south-central Monroe counties (Finley 1976).

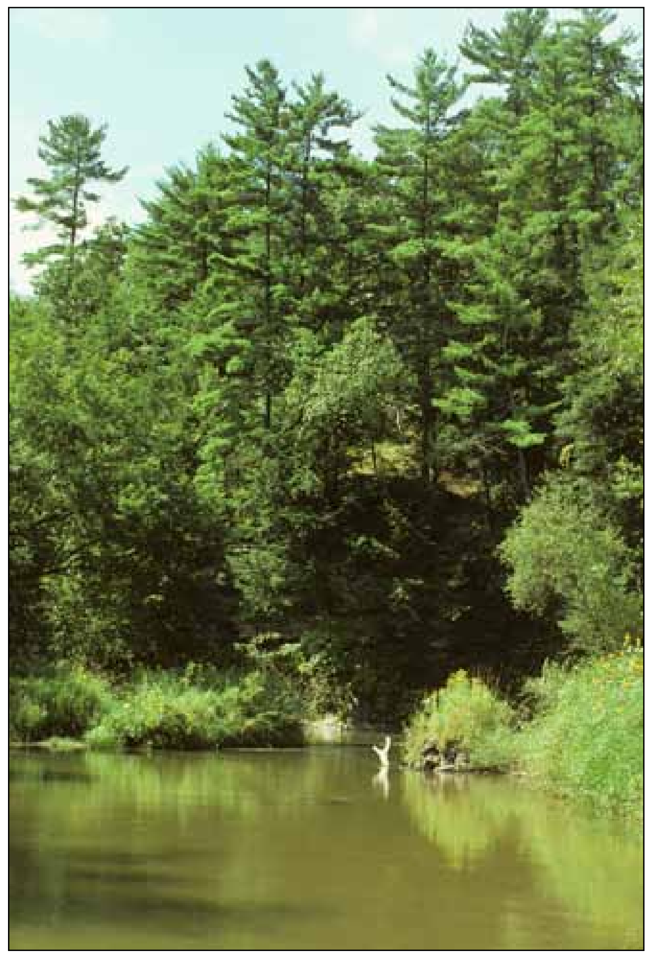
Threats to the pine forests of southern Wisconsin include the increase of shade-tolerant understory species in the absence of fire, grazing, the spread of invasive species, stand isolation, type conversion, and the loss of structure via the periodic removal of large trees. Long- and mid-term impacts of climate change are uncertain but could be significant, especially for jack and red pines.



This mature forest of large red and white pines occurs on the sandy slopes of the Overmeyer Hills. In many areas, such stands are mixed with black and white oaks. Jackson County. Photo by Eric Epstein, Wisconsin DNR.

Maple-basswood ("northern hardwoods") is the next most common forest type group in the southern part of the state, occupying about 3% (520,000 acres) of the land area of Province 222. Among the canopy dominants are sugar maple, basswood, white ash, and, near Lake Michigan, American beech. Important associates include red oak, red maple, red elm, bitternut hickory (*Carya cordiformis*), and black walnut (*Juglans nigra*) (Curtis 1959).

The maple-basswood group most closely matches the Southern Mesic Forest natural community type, characterized by a dense canopy, high internal humidity, and adequate moisture throughout the growing season. The best-known understory plants of mesic hardwood forests are collectively termed the spring ephemerals. The true ephemerals complete their life cycle over a few short weeks in the spring, emerging shortly after the departure of frost from the soil and often



Stands of pine in the Driftless Area are often (not always) associated with exposures of sandstone (or less commonly, dolomite) bedrock along waterways such as the Kickapoo, Baraboo, and Pine rivers. These are referred to as "Pine Relicts" and often support other northern species as well as habitat specialists not found in the northern part of Wisconsin. This stand of white pine occurs on a sandstone cliff above the Kickapoo River in Vernon County. Photo by staff, Wisconsin DNR.

disappearing before the trees are fully leafed out. Trout lilies (*Erythronium albidum* and *E. americanum*), Dutchman's breeches (*Dicentra cucullaria*), spring beauty (*Claytonia virginica*), toothwort (*Dentaria laciniata*), and false rue anemone (*Isopyrum biternatum*) are among the characteristic spring wildflowers of mesic hardwood forests. Other herbs representative of this type include wild ginger (*Asarum canadense*), bishop's cap (*Mitella diphylla*), woodland phlox (*Phlox divaricata*), mayapple (*Podophyllum peltatum*), blue cohosh (*Caulophyllum thalictroides*), trilliums (*Trillium* spp.), and violets (*Viola* spp.)

Aspen and white birch forest types occupy 3% (431,000 acres) of the land area of Province 222. Stands often occur on grazed, high graded, or otherwise disturbed slopes in the Driftless Area and on a variety of site types at scattered locations throughout the Central Sand Plains and Central Sand Hills Ecological Landscapes. White birch frequently occurs on Driftless Area bluffs and slopes that formerly supported prairie or oak savanna vegetation, and it may become increasingly dominant in the absence of fire or under certain grazing regimes. White birch and aspen can also become abundant on slopes that are heavily logged as a short-term source of timber or to increase the area of open pasture. The understory vegetation of such stands has not been studied in detail, but anecdotal evidence and observations suggest that on disturbed sites such forests often support weedy species (some of them potentially invasive), nonnative graminoid plants, thorny or spiny shrubs, and generalist herbs that thrive in a variety of forest habitats (Rooney et al. 2004, Rogers et al. 2008). The majority of the aspen forests in the state are not recognized by community types because they are early successional transitional stages that would succeed to other cover types in the absence of additional disturbances such as clearcutting.

Lowland conifer forests (classified as the spruce-fir group by Forest Inventory and Analysis) occupy less than 1% (82,000 acres) of the land area of Province 222. The dominant tree in lowland conifer forests in southern Wisconsin is often tamarack. Northern white-cedar and black spruce occupy a very low total acreage of this type at a small number of locations. Sites supporting lowland conifers in southern Wisconsin include basins in the glaciated landscapes of the southeastern and east central regions and the vast poorly drained bed of extinct Glacial Lake Wisconsin in the Central Sand Plains Ecological Landscape (see the map of former Glacial Lake Wisconsin in Chapter 10, "Central Sand Plains Ecological Landscape"). A few conifer swamps exist as strongly

Mesic hardwood forests in southeastern Wisconsin often include a component of American beech, which can be a canopy dominant along with sugar maple and basswood. Relatively undisturbed stands of beech-maple forest are becoming increasingly scarce. Franklin, in western Milwaukee County. Photo by Emmet Judziewicz.

The groundlayer of this rich maple-basswood forest includes Dutchman's breeches, Adam-and-Eve orchid (Aplectrum hyemale)*, and the Wisconsin Threatened snow trillium. Southern Pierce County. Photo by Eric Epstein, Wisconsin DNR.*

This dense thicket of aspen saplings was the result of management activities intended to regenerate oak. Jackson County. Photo by Eric Epstein, Wisconsin DNR.

isolated remnants in Driftless Area valleys where groundwater flow and possibly cold air drainage have allowed the conifers and some other northern species to persist. These forest communities, which are widespread and characteristic parts of the vegetation mosaic north of the Tension Zone, support a complement of plants and animals that are uncommon or rare and highly localized in the south. The ecological viability of the southern lowland conifer swamps is now in question because so many of them have been subjected to damage from altered hydrologic regimes due to the impacts of activities such as ditching, diking, tiling, channelization, right-of-way construction, and clearing of land around the conifer swamps, all of which can affect water levels, water quality, and water behavior to the detriment of the lowland conifer forests, especially in the southern part of the state. In addition, many conifer swamps have been negatively impacted by grazing, excessive browse pressure from deer, changed successional processes due to altered disturbance regimes (such as an increase in tall deciduous shrubs and hardwoods in stands from which fire has been excluded), and the spread of invasive plants. Tamarack forests in southern Wisconsin, referred to as Tamarack (Rich) Swamp on the Wisconsin Natural Heritage Working List (WDNR 2009), are also affected by periodic infestations of the larch sawfly and other insects, and possibly, by the exclusion of wildfire. In the past, many tamarack swamps in southern Wisconsin were cleared and converted to muck farms. Because muck farms are capable of producing crops for a relatively short period of time, some of them are now being restored to wetlands (though our ability to restore them to lowland conifer forests is unlikely). Climate change is a factor that could potentially have negative impacts on lowland conifer forests in southern Wisconsin.

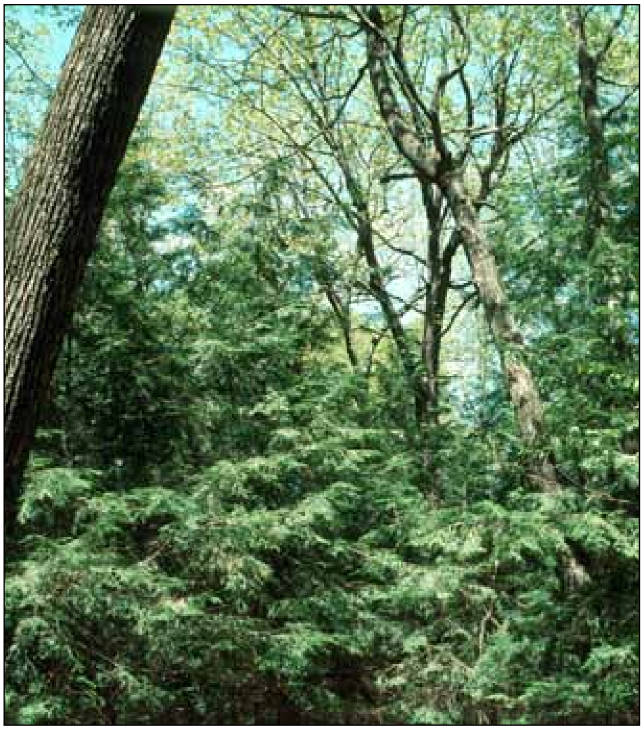
*Open "rich" tamarack swamp includes scattered sedge-dominated patches, alder (*Alnus *spp.), and abundant poison sumac* (Toxicodendron vernix). *Green Lake and Marquette counties. Photo by Andy Clark, Wisconsin DNR.*

Tamarack dominates this wet forest on the margins of Lake Beulah. The bright red plant closer to the shore is the native water-willow (Decodon verticillatus), *also known as swamp loosestrife. Walworth County. Photo by Eric Epstein, Wisconsin DNR.*

Several forest types of minor extent are not described separately by Forest Inventory and Analysis. At a few locations in the Driftless Area, cool, moist microsites support small stands composed of species characteristic of the Northern Mesic Forest community, including eastern hemlock and yellow birch. Understory plants typical of cool northern forests such as mountain maple (*Acer spicatum*), Canada yew, bluebead lily (*Clintonia borealis*), and others may be present. Geographically disjunct from the main range of this forest type, these Driftless Area ***relicts*** often support species that are regionally rare. ***Periglacial relicts***—species that for one reason or another were unable to retreat north as the climate warmed following the last glacial episode—occur in some of these stands. The "relict" species, including a number of land snails and several plants, are able to persist only in locations that are constantly moist and cold—conditions that are extremely rare and localized in southern Wisconsin today.

Other minor types include red cedar forest, which developed on sites subjected to grazing and the loss of periodic fire disturbance, and stands of northern white-cedar, eastern white pine, and eastern hemlock in clay ravines along Lake Michigan. There are also a handful of very small, isolated sites near southern Wisconsin's "northern edge" containing species associated with the Boreal Forest community such as white spruce, balsam fir, northern white-cedar, and American mountain ash (*Sorbus americana*). Finally, plantations of black walnut as well as species not native to Wisconsin such as Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and American chestnut (*Castanea dentata*) can also be found in this region.

Forested parks and reserves in urban areas are an important component of southern Wisconsin's cities, both as a source of open space for recreation and for wildlife habitat. A variety of wildlife species are found in these areas, but the near proximity and abundance of humans usually makes urban locations unsuitable for long-term habitation by less common species. Some urban areas may provide important stopovers during migration periods for rare birds, but they are unlikely



Dense eastern hemlock under an overstory of large red oak, white oak, and white pine. This is a rare and highly localized natural community type in southern Wisconsin, where it is referred to as "Hemlock Relict" and is often associated with moist or dripping sandstone cliffs. Kickapoo Reserve, Vernon County. Photo by Eric Epstein, Wisconsin DNR.

to remain there for more than a few days. Forested parks and reserves, as well as trees planted along streets and in yards of residences or commercial lots, provide many ***ecosystem services*** for urban dwellers. They keep the area cooler in summer, reducing energy demands for air conditioning. Conifers in particular provide wind protection that reduces heating needs in winter. Urban trees offer shade and some degree of protection from ultraviolet radiation. They intercept precipitation, allowing its absorption into the soil, thereby reducing erosion. Trees also mitigate the effects of some pollutants by utilizing carbon and nitrogen. They are aesthetically pleasing and often are highly valued by urban residents.

The cultivation of both native and nonnative trees gives urban forests a variety of species. However, in the past, single tree species were planted along streets in some cities, which can lead to the elimination of these trees if a disease affecting that species becomes established (e.g., American elm and Dutch elm disease or ash and the emerald ash borer). Urban homeowners tend to favor fast-growing tree species that are easy to care for, but some nonnative trees such as Norway maple (*Acer platanoides*) have created problems when they spread from planted areas. Many of our native tree species have difficulty surviving in urban areas because of pollution, soil compaction, lack of soil moisture, and competition with aggressive nonnative plants.

Nonforested lands occupy about 68% (11.4 million acres) of the land area of Province 222. (Reserved and unproductive forests are included in the FIA acreage for this estimate of nonforested lands.) Nonforested lands include savannas and barrens (with less than 17% tree cover), prairies, grasslands (including hay fields, pasturelands, and CRP fields), and various types of nonforested wetlands as well as agricultural lands and areas that have been developed for residential, commercial, industrial, and transportation uses. (See the community sections in this chapter for descriptions of oak savannas, barrens, grasslands, and wetlands.)

Natural Community Types

The Natural Heritage Inventory Program tracks eight southern forest natural community types in Wisconsin (see Table 2.2). In general, these types occur south of the Tension Zone. As with the northern forest communities, these natural community types do not directly translate to FIA cover types, but relationships can be examined without a great deal of effort. See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin," for additional descriptive and distribution information.

Similar to northern Wisconsin, southern forest communities often occur with nonforested natural community types. For example, a Southern Dry Forest could be associated with an Oak Opening or Dry Prairie. Other nonforested or sparsely forested areas of southern Wisconsin may contain grasslands (largely agricultural fields or old fields), wetlands, or aquatic communities.

Historical Vegetation of the Mid-1800s

Historically, southern Wisconsin's communities included, in order of relative abundance, broad-leaved deciduous forest, oak savanna, coniferous forest, prairie, and open wetland. Conifers were limited in distribution south of the Tension Zone, with the greatest acreage in the Central Sand Plains and the Central Sand Hills Ecological Landscapes and quite localized distributions elsewhere. Estimates of the extent of southern forest communities vary depending on the vegetation classification scheme and mapping methods used (Curtis 1959, Finley 1976, Schulte et al. 2002). Before Euro-American settlement, the southern forests were much different than they are today. The early explorers, missionaries, and settlers described open, "park-like" forests dominated by widely spaced oaks with a paucity of shrubs or saplings. The oak forests, woodlands, and savannas were interspersed with prairies and wetlands and some areas of maple-dominated forest.

Classification and description of the historical forests of southern Wisconsin is complicated by data gaps, ambiguities in the information, and the wide variety of ecosystems that exist. Southern Wisconsin contains both glaciated and unglaciated areas and a wide range of soil, hydrologic, and topographic conditions. There are very few tracts of "original" vegetation remaining to serve as reference areas for study and description. Formerly widespread and abundant fire-dependent communities such as the tallgrass prairies and oak savannas have been almost completely obliterated; less than 1% remains of the acreage estimated to have occurred prior to Euro-American settlement persists today.

Finley's forest type categories for southern Wisconsin prior to Euro-American settlement (Finley 1976) are described below. See Appendix C, "Data Sources Used in the Book," in Part 3 ("Supporting Materials") for more information about these data. Maps depicting forest cover of the mid-1800s are also available in Appendix G, "Statewide Maps."

Forested Types. White oak-black oak-bur oak forest types occupied 28% (about 4.7 million acres) of Province 222, mainly in the Western Coulees and Ridges, Central Sand Hills, and Southwest Savanna Ecological Landscapes. The major disturbance regime was fire, which created a range of conditions from closed forests, to open, park-like forests, to savannas. Grazing and browsing by native ungulates, including elk and white-tailed deer, likely influenced forest development and species composition. Where fire was not frequent, mesic forests of sugar maple-basswood prevailed, provided that substrate and moisture conditions were appropriate. Oak woodlands are an additional structural condition that has been proposed as intermediate between closed forests and savannas, but no extant examples of this natural community type are available to provide the basis for a detailed description. The Oak Woodland community is thought to have had relatively high canopy closure (50% to almost 90%) and an open understory resulting from frequent ground fires of relatively low intensity.

Sugar maple-basswood with red oak, white oak, or black oak as major associates occupied about 14% (2.4 million acres) of Province 222. The largest area of this forest type occurred in a large triangular-shaped area within the Western Coulees and Ridges Ecological Landscape covering most of what is now Richland County and portions of the surrounding counties (Finley 1976) in a ***fire shadow*** created by the Kickapoo River valley. Large areas of this type also occurred in the Southeast Glacial Plains Ecological Landscape and in a smaller area bordering the Western Coulees and Ridges and Western Prairie Ecological Landscapes. The major natural disturbance in these mesic forests was windthrow, which created small forest gaps at relatively frequent intervals. Large, extensive wind disturbances were probably uncommon, since they were seldom referenced in the GLO public land survey notes (Schulte and Mladenoff 2005). However, some larger gaps created by wind or fire would have been necessary to initiate development of the oak component in these forests. Grazing by native ungulates may also have played a role in forest succession.

American beech-sugar maple-basswood forest with red, white or black oak as major associates occupied about 0.4% (60,000 acres) of Province 222. This forest type occurred in a long narrow north-south belt along Lake Michigan on both sides of the Tension Zone. Most of the area was within the Central Lake Michigan Coastal Ecological Landscape, where climatic moderation due to the lake causes the Tension Zone to shift southward. In this unique climatic zone, eastern hemlock, eastern white pine, and northern white-cedar occurred as far south as Milwaukee County. Wind was the dominant disturbance, creating small forest gaps in which the shade-tolerant trees regenerated. Occasional larger gaps or fires

Table 2.2. *Southern forest natural community types with state and global ranks as of 2011 (see Wisconsin Natural Heritage Working List, http://www.dnr.wi.gov/, keyword "NHI" for more information).*

	State Rank[a]	Global Rank[b]
Upland Forests		
Central Sands Pine-Oak Forest	S3	G3
Hemlock Relict	S2	G2Q
Pine Relict	S2	G4
Southern Dry Forest	S3	G4
Southern Dry-mesic Forest	S3	G4
Southern Mesic Forest	S3	G3?
Wetland Forests		
Floodplain Forest	S3	G3?
Southern Hardwood Swamp	S2	G4?
Southern Tamarack Swamp (Rich)	S3	G3

[a]State ranks:
S1 – Critically imperiled in Wisconsin because of extreme rarity, typically five or fewer occurrences and/or very few (<1,000) remaining individuals or acres, or because of some factor(s) making it especially vulnerable to extirpation from the state.
S2 – Imperiled in Wisconsin because of rarity, typically 6 to 20 occurrences and/or few (1,000–3,000) remaining individuals or acres, or because of some factor(s) making it very vulnerable to extirpation from the state.
S3 – Rare or uncommon in Wisconsin, typically 21 to 100 occurrences and/or 3,000–10,000 individuals.
S4 – Apparently secure in Wisconsin, usually with >100 occurrences and >10,000 individuals.
S5 – Demonstrably secure in Wisconsin and essentially ineradicable under present conditions.

[b]Global ranks:
G1 – Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2 – Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3 – Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single state or physiographic region), or because of other factor(s) making it vulnerable to extinction throughout its range; typically 21 to 100 occurrences. A question mark indicated that there is a level of uncertainty regarding the global rank and G3 is the most likely rank, based on current information.
G4 – Uncommon but not rare (although it may be quite rare in parts of its range, especially at the periphery) and usually widespread. Typically >100 occurrences.
G5 – Common, widespread, and abundant (although it may be quite rare in parts of its range, especially at the periphery). Not vulnerable in most of its range.
GNR – Not ranked.

would have initiated oak development. Lake effect snows and ice storms would have also played roles in forest development.

White pine-red pine forest occupied about 2% (335,000 acres) and jack pine, scrub oak, and barrens about another 5% (830,000 acres) of Province 222. These pine-dominated areas were mostly located in the Central Sand Plains and Central Sand Hills Ecological Landscapes.

Other important historical types described by Finley (1976) included the lowland hardwood forests, which were found in poorly drained depressions in glaciated areas and within the floodplains of the major rivers. Lowland hardwoods occupied about 1% (220,000 acres) of Province 222. Floodplain forests were particularly well developed within the Driftless Area along the Mississippi, Wisconsin, Chippewa, and Black rivers. Significant stands were also present in eastern Wisconsin along the lower Wolf and Milwaukee rivers and along the Sugar River in south central Wisconsin. Important trees of the lowland forest included American elm, silver maple, green ash, river birch, swamp white oak, hackberry, cottonwood, and black willow. Swamp conifers, including tamarack, northern white-cedar, and black spruce, occupied about 4% (650,000 acres) of Province 222. The aspen, white birch, and pine forest type occupied less than 1% (80,000 acres).

Historical Nonforest Vegetation. Oak openings – bur oak-white oak-black oak occupied 20% (about 3.4 million acres) of the area in the Southwest Savanna, Southeast Glacial Plains, and Western Coulees and Ridges Ecological Landscapes. This savanna community (further discussed in the "Oak Savanna Communities" section of this chapter) occurred as a transition between oak forest and prairie. The extent of this community type was likely quite dynamic, depending on the frequency, severity, and seasonality of wildfire. Fire was the major disturbance regime responsible for both creating and maintaining the savannas.

Marsh and sedge meadow covered about 7% (1.2 million acres) of the land area. Wet prairie occupied about 10% (1.7 million acres), and approximately 4% (670,000 acres) was lowland shrub vegetation. Very few details on nonforest vegetation are available from the federal public land survey.

Global/Regional Context

Ecoregions with climate and soils similar to those of southern Wisconsin are not common worldwide. They can be found in Europe, in parts of Poland and Germany, and in an area of far-eastern Asia that includes portions of the Koreas, China, and Russia (Bailey 1996). The forest communities of southern Wisconsin are within the ***temperate broadleaf forest vegetative biome***, but in Wisconsin and similar ecoregions, composition is limited to species that can tolerate relatively hot summers with occasional periods of drought.

Oaks are common tree species of the ecoregion and one of the most important types of woody plants in the Northern Hemisphere. They have been a major source of fuel, animal feed, and lumber. Acorns were historically an important food for indigenous people in North America, Europe, and Asia.

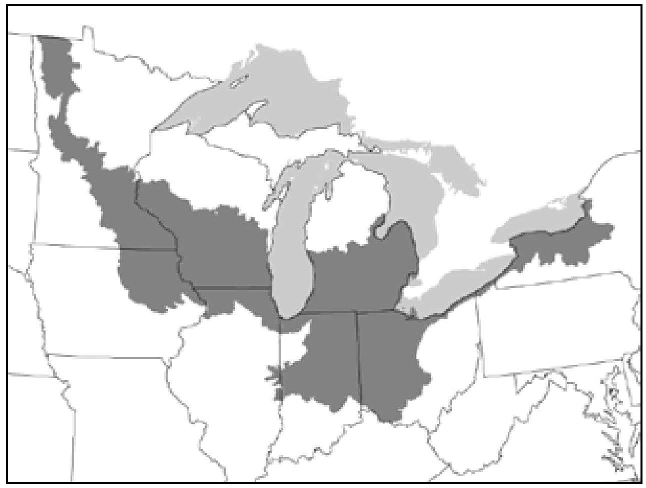


Figure 2.19. *The Eastern Broadleaf Forest Province (222) is shown shaded. Province 222 includes parts of Minnesota, much of the Lower Peninsula of Michigan, and parts of New York, Ohio, Indiana, Kentucky, Tennessee, Illinois, and Missouri (Keys et al. 1995). In Wisconsin, the northern boundary of Province 222 lies along the Tension Zone.*

Southern Wisconsin forests lie within the ecoregion known as Province 222, the Eastern Broadleaf Forest Province, as classified in the National Hierarchical Framework of Ecological Units (NHFEU) (Cleland et al. 1997) and shown in Figure 2.19. Province 222 is characterized by a hot continental climate with hot summers and cool winters, supporting natural vegetation dominated by broadleaf deciduous forest. Section-level ecological units include (1) the Southwestern Great Lakes Morainal Section (222K); (2) the North Central U.S. Driftless and Escarpment Section (222L); (3) the Minnesota and North Eastern Iowa Morainal Section (222M); and (4) the Wisconsin Central Sands Section (222R). See the NHFEU map in Appendix G, "Statewide Maps," in Part 3 of the book ("Supporting Materials").

Current Assessment of Southern Forest Communities

Current conditions in the southern forest are a result of interactions between the physical and biological environment and the history of land use by humans. The history of factors that have shaped or otherwise influenced ecosystem development is important for helping us understand today's forests in southern Wisconsin.

Changes Following Euro-American Settlement

The agricultural period began in southern Wisconsin in the 1830s after treaties were signed with the Wisconsin tribes. Lands were surveyed, and farmers began claiming the land and clearing forests and savannas. Southern Wisconsin's fertile soils and milder climate made it suitable for many agricultural uses, which led to dramatic changes in the composition, configuration, context, and extent of native vegetation. The fertile prairies, savannas, and forests were quickly cleared and converted to cropland or pasture by Euro-American immigrants during the 19th century.

The greatest loss of forest occurred in the gentler terrain of the glaciated southeastern and south-central portions of the state. In the more rugged Driftless Area of southwestern Wisconsin, the steeper side slopes have generally remained forested, though the broader ridge tops and flat valley bottoms were converted to cropland or pasture wherever possible. The slope forests were often used by local landowners as sources of lumber and firewood, and many of them were also grazed. The infertile, coarse-textured soils and extensive wetlands of central Wisconsin made that region less suitable for agriculture than other areas in Province 222. Extensive forests occur there today, in part because of fire suppression that has allowed the barrens and savanna communities to succeed to oak and pine forests.

Early logging in the forests of southern Wisconsin has not been extensively documented. One description of logging in the Baraboo Hills area comes from Lange (1990), who noted that settlers cleared land for housing, cultivation, and pasture. Although some wood was used as building material, fences, or fuel, most was burned in huge piles at celebrations called logging bees. Additional smaller uses included lime processing for fertilizer, plaster, or mortar; charcoal production for smelting ore; and specialized refining for bolts and hoops.

Eastern white pine logging began near the major rivers in the 1830s. Waterways were of prime importance for transporting logs to populated areas such as Chicago and St. Louis before the railroad system became well established in the 1870s. The main rivers used in southern Wisconsin were the Wisconsin, Chippewa, Black, Rock, Fox, and lower Wolf. Some rivers impacted by logging became clogged with sediment and were structurally altered by the ***wing and sluice dams*** that were built to facilitate log drives. Toward the mid-1800s, pine logging moved northward as large numbers of Euro-American settlers entered Wisconsin, and the pineries that existed in Wisconsin's Central Sands region (a region of the state that incorporates the Central Sand Plains and Central Sand Hills Ecological Landscapes), the Baraboo area, and along the Black and Kickapoo rivers were quickly exhausted.

Unlike northern Wisconsin, where the lasting Euro-American impacts were mainly on forest composition and structure, settlement here often meant outright elimination of forests and conversion of the land to agriculture. In addition, southern forests were frequently grazed by livestock after they were logged. Wildfires were suppressed in order to protect homes, other structures, and crops. Oak savannas were converted to farmland or succeeded to oak forests.

Current Conditions

Total acreage of the present day southern forest increased by about 6% between 1983 and 1996 and another 11% between 1996 and 2008 (USFS 2010). However, land use and ownership patterns have resulted in significant forest fragmentation throughout southern Wisconsin (Figure 2.20). Outright forest loss has been widespread in the areas suitable for agricultural and residential development. Another major change was the conversion of open and semi-open prairie and savanna landscapes, which succeeded to closed-canopy forest following the exclusion of periodic fire. In many areas, the canopy composition of the southern forest is now steadily shifting from oak dominance to shade-tolerant mesic hardwoods, primarily due to the absence of the formerly widespread fire disturbances that maintained large acreages of oak forest.

This situation is exacerbated by the selective removal (high grading) of the commercially valuable oaks by landowners and loggers (WDNR 2000). Stands that have been high graded usually have poor regeneration of the valuable

This landscape was historically forested but is now devoted almost entirely to agricultural uses. Habitat fragmentation is extreme, and most of the remaining forests are on sites that are too wet to cultivate. Lower Wolf River Basin, Outagamie County. Photo by Eric Epstein, Wisconsin DNR.

Figure 2.20. *Forested lands in Wisconsin, Iowa, Illinois, Indiana, Michigan, and Minnesota. Data source: National Land Cover Database (MRLC 2011).*

oaks, and the residual trees are mostly other hardwood species of lower economic value. Unfortunately, high grading remains a common practice in southwestern Wisconsin.

Timber harvest levels in Province 222 increased 165% from 1983 to 1996 and another 4% from 1996 to 2008. The majority of this large increase occurred in the central and southwest portions of the state where harvest levels increased most dramatically for red and white oaks as well as for hickory, soft maple, and black walnut.

Red oak has consistently been the most harvested species for the last 25 years in Province 222, and removals have ranged from two to four times the levels of white oak, the next most harvested species in each of the 1983, 1996, and 2008 FIA sampling periods. For the most part, growth has exceeded removals, with some key exceptions. Northern red oak removals far exceeded net growth, based on the 1996 FIA data when an average of nearly 37 million cubic feet were removed annually, while only 17 million cubic feet were gained in net annual growth. Although the 2008 FIA data show a nearly equal balance between growth and removals for red oak (roughly 20 million cubic feet in both the growth and removal categories), there are concerns within both forestry and ecological circles for oak's dominance in the future as a result of widespread regeneration problems on mesic and dry-mesic sites. Also, many large oaks are now reaching their maximum economic return, and there are difficult trade-offs regarding harvest of these oaks versus trying to maintain oaks on a site for as long as possible in areas where regeneration is very difficult. Species exhibiting large levels of growth relative to removals in Province 222 include red maple and red pine, both exhibiting levels of growth that are two to three times that of removals based on 2008 data. It is important to note that red maple is replacing red and white oaks in many localities, a condition that has probably been accelerated by the increased harvest pressure on large oaks; virtually all of the red pine in southern Wisconsin has been planted (WDNR 2010).

Prescribed fire has been used in one of these stands of black and white oaks to control shrubs and saplings that would prevent the oaks from reproducing. Quincy Bluff State Natural Area, Adams County. Photo by Eric Epstein, Wisconsin DNR.

Over the last 150 years there has been dramatic fragmentation of the southern forest. Due to the increasing human population and associated development pressures, there are few remaining large blocks of forested land in the southern forest. The average size of private nonindustrial forestland parcels declined from 36 to 30 acres between 1984 and 1997 in southern Wisconsin. By comparison, in northern Wisconsin parcel size declined only slightly, from 44 to 43 acres, during the same time period (Roberts et al. 1986, Leatherberry 2001).

The length of time that a landowner retains ownership of forested land is a factor in parcelization. As land prices increase there is a greater chance the parcel will be subdivided at each succeeding sale. In 1997 landowner tenure in southern Wisconsin (19 years) was slightly less than in northern Wisconsin (20 years) (Leatherberry 2001). Remaining large tracts of southern forest are in areas that were not developed due to nutrient-poor conditions, public ownership, low commercial value, or relative inaccessibility (e.g., rough topography, susceptibility to flooding).

Forests over 100 years in age are almost entirely lacking, and their abundance has continually decreased statewide for the last 25 years, based on FIA data (USFS 2010). Although much of southern Wisconsin was dominated by fire-driven natural communities prior to Euro-American settlement, there were large areas of mature hardwood forests that are now all but eliminated from the landscape, especially in eastern Wisconsin (Finley 1976).

The ecology of the southern forests is also being affected by nonnative species. Unlike much of the northern forests, the southern forests have been widely colonized by invasive plants. Nonnative common buckthorn, glossy buckthorn, honeysuckles (e.g., *Lonicera morrowi* and *L. tatarica*), and garlic mustard are especially troublesome on upland sites. Glossy buckthorn is also a serious problem in some lowland forests, although it has also invaded upland sites in some areas. Reed canary grass often invades bottomland forests after a disturbance like a windstorm or timber harvest and can limit or prevent tree regeneration. Other problematic invasive species of southern forests include Japanese barberry, multiflora rose, Oriental bittersweet (*Celastrus orbiculatus*), and moneywort (*Lysimachia nummularia).* Invasive trees include the nonnative Norway maple, black locust, and white mulberry (*Morus alba*). When abundant, invasive plants alter forest composition and structure and can ultimately affect successional patterns and future forest conditions (Hoffman and Kearns 1997).

Faunal species composition and relative abundance in the southern forests have changed dramatically from historical times. The large herbivores such as American bison and elk were abundant historically but were extirpated as were their major predators, the cougar (*Puma concolor*) and gray wolf. Wolves are now reestablished in the Central Sand Plains Ecological Landscape but are uncommon in the rest of Province 222. Black bear and bobcat are uncommon, and the fisher has only recently recolonized a small portion of the southern forests, primarily in the Central Sand Plains. The Wild Turkey, extirpated in the late 1800s, was reintroduced to the state in the mid-1970s by the Wisconsin DNR and various partners and is now widespread. The now-extinct Passenger Pigeon would have had a great impact on the dynamics of the southern forest because of its sheer numbers and habits. Flocks of Passenger Pigeons consumed vast quantities of acorns and beechnuts and may have been dispersal agents for those species (Schorger 1955).

Although there is a paucity of data, it is generally believed that white-tailed deer were relatively common before Euro-American settlement times (perhaps 20–50 deer per square mile). White-tailed deer populations declined to very low numbers during the period after Euro-American settlement as a result of subsistence and market hunting and conversion of land to agriculture (Dahlberg and Guettinger 1956). Deer numbers remained low until the late 1960s, when populations began to increase. In prime habitats in southern Wisconsin, deer densities have now reached 100 per square mile. Deer herd densities are significantly altering forest composition through herbivory, especially impacting the herbaceous layer but also reducing regeneration success of some tree species (Wisconsin Conservation Congress 2001). Recently, white-tailed deer have begun using suburban areas and parks. Deer densities in these areas can be even higher than in rural areas, leading to extensive damage of landscaping plants as well as remnant native vegetation. ***Chronic wasting disease*** (CWD) was discovered in the southeastern part of the Western Coulees and Ridges Ecological Landscape (Dane and Iowa counties) in 2002. Since then, special hunting seasons and regulations have been implemented to reduce the deer herd and contain the disease. Reduction of the deer herd, if accomplished, could relieve browsing pressure on oak seedlings and browse-sensitive plants in southern forests, aiding additional oak regeneration and allowing browse-sensitive plants to recover.

This remnant dry-mesic oak forest has been grazed and repeatedly high-graded to extract sawlogs. These are common practices in western Wisconsin's oak forests. Dense thickets of Japanese barberry now dominate the understory. Maintenance of oak on sites managed in this way is virtually impossible. Monroe County. Photo by Eric Epstein, Wisconsin DNR.

In addition to the serious impacts of herbivory by white-tailed deer, there are a number of other important factors that negatively impact native plant diversity in southern Wisconsin's forests. These include permanent forest fragmentation, isolation of remnant forest patches, persistent livestock grazing, high grading of large canopy trees and lack of subsequent regeneration, the continued spread of invasive nonnative plant and animal species, and human use impacts such as trampling, vehicle use, disruption of hydrology, and residential development. These factors can alter the composition and structure of vegetative communities through competition, changed habitat conditions (light, humidity, soil moisture, soil structure, allelopathy), direct elimination of native species (by grazing, trampling, development, etc.), or by limiting the ability of plant seeds or pollinators to disperse between forest fragments. Changes in forest plant community structure and composition can in turn interfere with the habitat requirements of some wildlife species (Wisconsin Conservation Congress 2001).

The exotic emerald ash borer has recently been discovered at several locations in southern Wisconsin. Infestations of this insect have the potential to devastate hardwood forests in which any of our native ashes are significant components. The Wisconsin Threatened blue ash (*Fraxinus quadrangulata*), known from only two state locations, both in southeastern Wisconsin, is vulnerable to attack by this insect.

Beech bark disease, a serious pest of American beech, was found recently in Door County and has already spread to beech forests elsewhere in Wisconsin (Marinette, Oconto, Kewaunee, Manitowoc, Sheboygan, and Ozaukee counties). Other major threats for forest composition include gypsy moth (oak forests) and annosum root rot (*Heterobasidion annosum*) (pine forests).

Many rare species inhabit southern forests. The Wisconsin Wildlife Action Plan (WDNR 2005) documented 54 vertebrate Species of Greatest Conservation Need (SGCN) that are associated with southern forests. Of these 54 SGCN, 29 are birds, 14 are herptiles, and 11 are mammals. In addition, there are also rare invertebrate species that use southern forests. Many rare plants depend on southern forests for their habitat. Among the rare forest plants are the Wisconsin Endangered bluestem goldenrod (*Solidago caesia*) and the Wisconsin Threatened snow trillium *(Trillium nivale*) and forked aster (*Aster furcatus*). Some rare plants and animals are dependent on distinctive microsites that occur within forest environments, such as seepages, ephemeral ponds, structural elements such as coarse woody debris, or rock outcroppings. The Wisconsin DNR's Bureau of Endangered Resources has responsibility for state and federally listed species as well as many ***nongame*** species and is in the process of developing management guidelines for rare species that use southern forest habitats.

The size and landscape context of a forest patch can also affect native plant species diversity. Some of the earlier studies that examined these issues reported that tree species composition and structure in southern Wisconsin were affected by shade-intolerant edge species in isolated forest fragments of up to 20 acres, with edge effects penetrating farthest into drier sites (Guntenspergen 1983). (Note that these shade-intolerant edge species were mostly weedy, nonnative generalists, not sensitive native species adapted to more open savanna or woodland conditions). On more mesic sites of up to 13 acres, the effective forest interior where shade-tolerant trees could thrive was significantly reduced. In formerly forested landscapes elsewhere in eastern North America that now consist of small isolated forest remnants surrounded by development or agriculture, substantial loss of interior habitat has been documented and is persistent. Tracts up to roughly 250 acres exhibited negative edge effects such as reduced species richness, declines in cover of native understory plants, and increases in nonnative species on 14% of the total area (Fraver 1994). Current forest plant research throughout Wisconsin has raised concerns that these effects are both more pervasive and more persistent than earlier work had shown. Apparent trends noted in southern Wisconsin forests include a significant increase in woody stem density of both native and nonnative species and an overall loss of species richness. The loss of species richness becomes especially dramatic when nonnative species are removed from consideration. The presence and cover values of nonnative plants have greatly increased, while rare and even some formerly common native forest plants have shown the greatest declines. Once they have been lost from a site, many native forest herbs will likely remain excluded from areas they previously inhabited because of competition from recently established and spreading invasive species, difficulties in dispersing between isolated fragments, loss of pollinating insects, and continued browse pressure from large herbivores (Rooney et al. 2004, Rogers et al. 2008).

Birds of high conservation concern in southern Wisconsin's forests include the following: Cerulean Warbler (*Setophaga cerulea,* listed as *Dendroica cerulea* on the Wisconsin Natural Heritage Working List; WDNR 2009), Worm-eating Warbler (*Helmitheros vermivorum,* listed as *Helmitheros vermivorus* on the Working List), Kentucky Warbler (*Geothlypis formosa,* listed as *Oporornis formosus* on the Working List), Prothonotary Warbler (*Protonotaria citrea*), Hooded Warbler (*Setophaga citrina,* listed as *Wilsonia citrina* on the Working List), Canada Warbler (*Cardellina canadensis,* listed as *Wilsonia canadensis* on the Working List), Acadian Flycatcher (*Empidonax virescens*), Golden-winged Warbler (*Vermivora chrysoptera*), Blue-winged Warbler (*Vermivora cyanoptera,* listed as *Vermivora pinus* on the Working List), Wood Thrush (*Hylocichla mustelina*), and Red-headed Woodpecker (*Melanerpes erythrocephalus*) (all of the birds listed here are Wisconsin Species of Greatest Conservation Need). They were identified as species at risk by the Wisconsin Bird Conservation Initiative (WBCI), a coalition of over 120 Wisconsin groups interested in bird conservation. WBCI bases the risk assessment on a planning process developed by Partners in Flight (Knutson et al. 2001). WBCI will be working through its endorsing partners in a variety of ways to implement the Partners in Flight plan in Wisconsin. The plan has outlined conservation opportunities for priority bird species with respect to habitat restoration, though for the Cerulean Warbler, due to its widely perceived rarity, more extensive levels of monitoring

Nodding pogonia (Triphora trianthophora) *(Wisconsin Special Concern) is known in Wisconsin from only a few counties, where it inhabits mesic to dry-mesic hardwood forests. Photo by Thomas Meyer, Wisconsin DNR.*

and additional guidelines for habitat restoration are being proposed or are under development. Specific habitat conservation issues identified in the plan include fragmented or otherwise altered forests, fire suppression, wetland loss, and intensive agriculture that has eliminated oak savannas and prairies.

Studies of bird habitat in southern Wisconsin's forests have identified increasing tract size as an important factor in bird diversity and especially the abundance of long-distance migrant species (Ambuel and Temple 1983, Temple 1988). Mossman and Hoffman (1989) summarized results of a number of studies of breeding birds, noting that isolated tracts of 40 or even 80 acres were dominated by generalist species. These smaller forest patches are dominated by edge habitats, unsuitable for interior forest-dwelling species. A number of bird species were found primarily in tracts of 100 acres or larger, and several species such as Kentucky Warbler, Hooded Warbler, and Worm-eating Warbler were found to only breed consistently in tracts of forest exceeding 500 acres in size. Other rare or uncommon bird species that depend on large blocks of unfragmented forest for breeding habitat are also declining as patch size decreases or forest habitat is otherwise rendered unsuitable (Knutson et al. 2001). The Red-shouldered Hawk, Pileated Woodpecker (*Dryocopus pileatus*), Acadian Flycatcher, Wood Thrush, Louisiana Waterthrush (*Parkesia motacilla,* listed as *Seiurus motacilla* on the Wisconsin Natural Heritage Working List), Cerulean Warbler, and Black-and-white Warbler (*Mniotilta varia*) are among the other forest birds that do best in larger tracts of unbroken forest. Many birds and other species with more generalized habitat needs are now stable or increasing as populations of forest habitat specialists decline.

A study in the Baraboo Hills found closed-canopy forests, or those with gaps of a half-acre or smaller, were less likely to be impacted by the Brown-headed Cowbird, a significant nest parasite that reduces production of offspring for a variety of bird species. Here, Cowbird nest parasitism rates were higher in proximity to forest edges (Brittingham and Temple 1983). Cowbird impacts appear to vary with landscape factors. In the Driftless Area, these included the amount of forest cover and the size and shape of forest patches, which influence occupancy by suitable host birds. Cowbirds also require feeding sites within 3 miles of breeding habitat. Landscapes with intermediate levels of fragmentation, such as those

The Prothonotary Warbler (Wisconsin Special Concern) is a habitat specialist that breeds almost exclusively in lowland hardwood forests bordering southern Wisconsin's larger rivers and streams. This is our only wood warbler that nests in tree cavities, often in trees that overhang water. Photo by Mark Musselman, courtesy of U.S. Fish and Wildlife Service.

The Hooded Warbler nests primarily in extensive stands of hardwoods that include the dense patches of shrubs or saplings in which it builds its nest. The Kettle Moraine State Forest and the Baraboo Hills are two of our state's most important breeding areas for this Wisconsin Threatened species. Photo courtesy of U.S. Fish and Wildlife Service.

Ephemeral ponds provide critical habitat for certain amphibians and invertebrates. Many of these important features have been destroyed, damaged, or isolated by the intensive development and land uses that are now prevalent throughout much of southern Wisconsin. Mirror Lake State Park, Sauk County. Photo by Drew Feldkirchner, Wisconsin DNR.

The wood frog (Rana sylvatica) *breeds in various situations, but fishless ephemeral ponds are especially important habitats for this and several other amphibians. Photo by Dan Nedrelo.*

where forests cover 30% to 50% of the area, may offer Cowbirds foraging areas as well as host availability (Gustafson and Rasmussen 2002). Nest predation by species like Blue Jays (*Cyanocitta cristata*), American Crows (*Corvus brachyrhynchos*), raccoons, skunks, and free-ranging domestic cats is also a major negative impact on bird reproduction.

Mammals identified as SGCN that use southern forests include eastern red bat (*Lasiurus borealis*), silver-haired bat (*Lasionycteris noctivigans*), woodland vole (*Microtus pinetorum*), woodland jumping mouse (*Napaeozapus insignis*), and northern flying squirrel (*Glaucomys sabrinus*). Herptiles using southern forests include SGCN such as wood turtle (*Glyptemys insculpta*), timber rattlesnake (*Crotalus horridus*), eastern massasauga rattlesnake, and four-toed salamander (*Hemidactylium scutatum*).

The stands of forested floodplain bordering major rivers in southern Wisconsin are among the largest in the Upper Midwest and offer exceptional opportunities to maintain large, if somewhat linear, interconnected stands of interior forest. Particularly good examples occur along the Mississippi, Wisconsin, Chippewa, Wolf, and Black rivers. In a few places, such as along the lower Wisconsin River, these forested floodplains adjoin extensive tracts of upland forest. Management of such sites needs to be planned and implemented with great care at scales and with considerations far beyond the usual emphasis on managing individual stands or species. Other southern river systems, such as the Milwaukee, Root, Bark, Des Plaines, Kickapoo, Yellow, Lemonweir, Sugar, Pecatonica, Baraboo, and Montello, offer somewhat similar opportunities, though at reduced scales. All of these sites support rare forest species, and in some cases the habitats provided may be critical to the viability of those species in Wisconsin. Each of these sites is also associated with nonforested natural communities and other habitats of high significance, and some of the rivers and streams mentioned are exceptional for the sensitive aquatic life they support.

Ecological concerns in the southern forest generally focus on the loss, dramatic decrease, or alteration of communities that are important because of their extent, geographic distribution, or rarity. Natural disturbances, especially fire and flooding, do not function in today's landscape as they did in the past. Land use changes have led to ecosystem fragmentation, isolation, simplification, and significant declines of some species.

Issues of Composition, Structure, and Function

The boundaries between composition, structure, and function of an ecosystem are not always sharply defined. A change in composition can lead to a change in structure and ultimately a change in function. Issues are described within a category where effects are most apparent, but indirect effects also occur in other categories.

Composition

Southern forest communities continue to change as a result of an increasing number of natural and human-caused disturbances. In some cases, lack of disturbances such as fire have led, and continue to lead, to big changes in composition.

- Some major tree species have decreased in abundance due to the impact of diseases such as Dutch elm disease, oak wilt, and butternut canker. The species affected were formerly widespread and provided important wildlife habitat and forest products; they include the elms, the red oak group, and butternut. American elm was a dominant canopy species in bottomland forests; it had large stature and provided a long-lived structural feature with many nesting and foraging sites. American elm was also the most commonly planted shade tree in many cities, including Milwaukee.
- Other forest species are declining, sometimes for reasons that are poorly understood. Tamarack has experienced substantial dieback in much of its southern Wisconsin range. Its ability to persist, in at least some locations, is questionable. Oak forests are difficult to regenerate, particularly on mesic sites, and are being harvested at rates exceeding growth. Regeneration of bottomland forests has also become problematic due to altered flood regimes and diseases.
- Invasive species can change forest composition and, ultimately, structure and function. Nonnative invasive plants are now widespread and often dominate the understory of southern forests, reducing the abundance of, or eliminating, native plants. Some invasive plants inhibit regeneration of forest trees; examples include reed canary grass in bottomland forests, buckthorn in oak forests, and garlic mustard in relatively closed forests of many types. Some nonnative tree species commonly planted in urban areas are becoming invasive and spreading into woodlands where they compete with native trees. Invasive shrubs, vines, and herbs will likely continue to spread, limiting the reproduction of ecologically and economically important trees and

adversely impacting native plant communities. Forest diseases and insect infestations are a continual problem due to new introductions of nonnative species and changes in the invasiveness of existing pests. Infestations of the gypsy moth, a nonnative insect, may alter the future composition of southern forests, favoring those tree species that are less susceptible to attack or more resilient to defoliation. The native disease oak wilt is currently damaging various oak species. The exotic emerald ash borer has been discovered recently in southern Wisconsin and poses a severe threat to all of our native ashes, including the Wisconsin Threatened blue ash. Asian longhorned beetle (*Anoplophora glabripennis*) is a potential threat to maples and other hardwoods. Attempts to control diseases and other forest pests may have unforeseen secondary consequences.

- Poor management practices, such as high grading, continue to degrade forests by eliminating or diminishing the abundance of important canopy species (especially large oaks). These practices can produce shrubby growing conditions that allow ecologically and economically less desirable species to increase (e.g., red maple, cherries, ironwood [*Ostrya virginiana*]) while restricting regeneration of those tree species that are selectively removed, such as oaks and black walnut.
- Maintenance of glacial relict communities will remain a challenge due to management for other vegetation types, which may alter site context and conditions. Impacts of climate change might be especially deleterious for sensitive northern relicts in southern Wisconsin.
- Certain forest raptors and neotropical migratory songbirds have been identified as high priorities for conservation attention due to perceived rarity, threats, and/or declining populations (Knutson et al. 2001).

Structure

Structural forest attributes are important for wildlife and influence the types of species that will use an area. These attributes are important to consider at all scales.

- Large patches of forest habitat and connectivity between patches of forest are important for a variety of wildlife species. Fragmentation of forests through conversion to agricultural, residential, and urban uses has reduced suitability for many animal species that were formerly widespread in the southern forests. Historical landscape patterns have been altered, reducing forest patch size, increasing patch isolation, and altering the context for forest wildlife in ways that are not conducive to the maintenance of viable populations. Small patch sizes can be vulnerable to increased Brown-headed Cowbird parasitism, and nest predation is a limiting factor for many bird populations in small forest fragments. Population isolation is a serious consequence for those species with limited dispersal capabilities or for plants with animal pollinators that cannot easily move between habitat patches. Development in and around forests and conversion of forests to other types of vegetation and uses will undoubtedly continue for the foreseeable future.
- Logging practices, extreme weather events, and insect or disease outbreaks can damage or eliminate supercanopy trees, large canopy trees, snags, and potential coarse woody debris that provide niches critical to the survival of many forest organisms.

Function

Various stressors can limit the ability of southern forest ecosystems to function naturally. Some of these have existed for many decades while others are more recent phenomena.

- Older age classes of longer-lived species are generally lacking, resulting in a deficiency of certain niches for habitat specialists and affecting ecological processes such as decomposition and nutrient cycling.
- High densities of white-tailed deer have damaged and continue to negatively impact natural, agricultural, and urban vegetation. In a 2001 report, the Wisconsin Conservation Congress pointed out the impacts of white-tailed deer browsing on growth, forest composition, tree regeneration, and the ability of some plants to survive (Wisconsin Conservation Congress 2001). In southern Wisconsin, regeneration of oaks is reduced by herbivory, while less palatable species such as black cherry, bitternut hickory, and ironwood are not impacted and thus gain a competitive advantage.
- Hydrological disruptions such as dam construction, dredging, and ditching have altered the hydrologic regimes to which many lowland forest species are adapted.
- Lack of fire has altered historical successional patterns, resulting in the conversion of prairie and savanna to forest and shifting the composition and structure of forest types that formerly burned. Dense shrub and/or sapling understories have developed in many places, eliminating or reducing populations of plants that require open conditions. Shade-tolerant understory species have increased, especially in oak and pine forests. Some sites that are now densely forested with scrub oak or pines were historically sandy barrens habitats. Barrens vegetation continues to decline because of fire suppression, the continued increase in woody cover, and conversion to pine plantations.
- Wildlife diseases have recently become large concerns in Wisconsin. The long-term effects of chronic wasting disease in the white-tailed deer population are unknown at present. ***West Nile virus*** has the potential to negatively affect populations of many wildlife species.
- Livestock trampling contributes to the spread of nonnative plant species and can cause soil compaction and erosion.

- Pollution from acid deposition is not a severe problem in southern Wisconsin's forests. Elevated ground-level ozone concentrations, mostly produced by the combustion of fossil fuels, are causing foliar injury to ozone-sensitive plant species. Injury is most noticeable in counties along Lake Michigan, but injured foliage has been found throughout the state. The impact of this injury on plant communities is being studied, but the effects are difficult to assess because of interacting natural events and human factors. Pesticides have been shown to impact certain wildlife species, including some insects and amphibians, but effects on forest ecosystems as a whole are unclear.
- Extinct and extirpated animals that inhabited Wisconsin's southern forests include ***keystone species*** such as the Passenger Pigeon, cougar, and wolf. The Wild Turkey, extirpated from Wisconsin in 1881, was successfully reintroduced in the mid-1970s. The loss of keystone species has long-lasting effects on food webs.

Land Use and Environmental Considerations

Fragmentation of habitats in southern Wisconsin is severe and the former matrix of hardwood forest, savanna, and prairie has been largely replaced by agriculture. There are many competing uses for land, providing both opportunities and challenges for maintaining southern forest communities.

- Conflicts may sharpen among timber production, preservation, restoration, recreation, and wildlife management concerns. Reforestation or ***afforestation*** of open landscapes can conflict with grassland or savanna restoration management goals. Conversely, restoration of savanna and barrens habitats in forested landscapes can conflict with the maintenance or development of forest conditions. Diverse and often conflicting demands cannot easily be addressed within a limited land and forest resource base.
- Periodic disturbances, such as prescribed fire or other forest management activities needed to maintain economically desirable species like oaks in the southern forest, are often expensive and sometimes controversial.
- Changes in the tax structure or ordinances on parcel size can be disincentives to maintaining Wisconsin's southern forests. The "use value" method of assessing agricultural land has led to impacts on farm woodlots. One such impact is that cattle are increasingly allowed into woodlots to qualify them for the lower agricultural tax rate. Some locales have imposed minimum restrictions on parcel size in an effort to retain farmland, but this may contribute to landowners breaking large holdings into many medium-sized tracts rather than splitting off a few small lots and retaining a larger block. Incentives and landowner awareness are often inadequate for the development, maintenance, and restoration of large forested tracts.
- Forest habitats also continue to be directly lost to residential development. Parcelization is increasing for a variety of social and economic reasons and contributes to residential development.
- As infrastructure (e.g., roads, rail lines, and utility corridors) is expanded or upgraded, forests are subject to increased fragmentation, isolation, and colonization by invasive species. The placement of these features can disrupt hydrology, resulting in sedimentation, alteration of flow patterns and drainage, and the drying of springs and small streams.
- As their availability decreases, demand for oak and other economically desirable species will likely continue to increase. Species substitution may occur, materials may be shipped in from other areas, or forest products companies may leave, resulting in economic loss to the region. Sustainable production of forest products is needed to support economies over the long term.

Heavily pastured woodlot in southwest Wisconsin. Photo by Jeff Martin.

Fall hillside colors in the Baraboo Hills, Sauk County. Photo by Jeff Martin.

Statewide Ecological Opportunities for Southern Forest Communities

The following opportunities for the southern forest communities are provided from a statewide perspective and are meant to encompass all of the areas comprising the southern forest in Wisconsin.

Landscape-Scale Planning Opportunities

Planning at larger scales has many advantages from an ecological perspective. The following are some considerations for planning at a landscape scale for southern forests. See also Chapter 1, "Principles of Ecosystem and Landscape-Scale Management."

- All remaining large blocks of southern forest communities are of high ecological importance. The most extensive southern forests are associated with the major river corridors, portions of Wisconsin's Central Sands region, and areas with complex topography (see "Forested Areas of Conservation Concern" below). In addition, any forest remnant exceeding 240 acres—a rough threshold for some forest interior birds (Temple 1988, Mossman and Hoffman 1989, Paton 1994, Robinson et al. 1995, Donovan et al. 1997, and Flaspohler et al. 2001)—merits consideration for its potential to support area-sensitive species.
- At some locations there are opportunities to expand upon existing blocks of extensive forest. Good opportunities include the Kettle Moraine region (especially in the northern part of the Kettle Moraine), the Baraboo Hills, sites along the lower Wisconsin River (e.g., where the Kickapoo River flows into the Wisconsin), and in the western portion of the Central Sand Plains Ecological Landscape. Other areas affording significant opportunities to manage for extensive forests include parts of the lower Chippewa River drainage, the lower Wolf River drainage, the lower Black River drainage, the upper and middle Kickapoo River valley, and perhaps parts of the Mississippi River corridor.
- Reforestation could be beneficial in appropriate areas to connect blocks of forest or increase the size of existing blocks. In addition to improving habitats, forests and other natural communities can function to capture additional carbon, so tree planting is likely to become an important issue in the near future. Planning efforts will be needed to identify the most appropriate places for establishing forest as well as places that should be avoided because of rare species or other ecological priorities such as maintaining grassland habitats.
- Comprehensive biological inventories are needed to assist planning efforts, especially at large scales, as data are lacking for many areas.
- Landscape and regional-scale analyses can be used to identify representative and rare forest communities, patch sizes, and successional stages as well as establish ecological significance, conservation importance, and social values. Several recent sources of information can be used along with the ecological landscape chapters of this publication to assist in these efforts (e.g., TNC 2001, WDNR 2006, SEWRPC 2010).
- In the heavily urbanized parts of southern Wisconsin, there are opportunities to work with regional and urban planners, parks departments, foresters, universities, and land managers to further the restoration of forests and other plant communities, address ecological problems and potential use conflicts, and increase the protection of sensitive natural features.

Planning Opportunities at the Site Scale

At some point management opportunities must be addressed at finer scales. There are many opportunities to address ecosystem management concepts at these scales while incorporating considerations for how specific sites are related to the broader landscape.

- Remaining intact examples of forests on nutrient-rich soils, such as those once commonly associated with nutrient-rich gently rolling till plains, are significant conservation and management opportunities because they are now quite scarce. Examples include mesic hardwood types such as beech-maple and maple-basswood forests. Fragmentation impacts in areas formerly dominated by these forest communities are generally severe.
- Site-level management plans provide important opportunities for ecosystem management if they consider ecological context, successional stages, patch sizes, habitat needs of sensitive species, and connectivity to adjoining or nearby forests.
- There are opportunities for site-level planning to be informed by landscape-scale considerations such as local, regional, and statewide representation of various forest communities and trends in their abundance and condition.
- Management guidelines are being developed for a group of sensitive southern forest species, and there are plans to work on additional species. This information can inform planning and management activities to help maintain or enhance viable populations of these species in southern Wisconsin.
- Small, perhaps even isolated, stands can provide good, or perhaps the only, conservation opportunities for forest communities, successional stages, developmental stages, patch sizes, and floristic components that are now very scarce. Ecologically important opportunities exist for small areas with characteristics not represented elsewhere, stands of exceptional composition and structure, or forests that occur at strategic locations (e.g., on the Lake Michigan shoreline, along streams, or as integral parts of larger vegetation mosaics with significant ecological values).

- Efforts will be needed to manage use conflicts effectively since there will be increasing demands on the southern forests for various uses by a variety of groups.

Forest Management Opportunities

Numerous management opportunities exist for southern forest communities. Many of these are best addressed directly through forest management.

- Fire is often used in ecological restoration activities, but its use as a silvicultural tool has, thus far, been extremely limited in Wisconsin. The use of prescribed fire can aid in the regeneration and maintenance of fire-dependent forest communities and associated species by reducing the density of encroaching mesophytic shrubs and saplings, releasing nutrients, and preparing seedbeds suitable for the establishment of some species (Grigal and Bates 1992, Abrams 2005, Nowacki and Abrams 2008). Oak and pine forests may be especially appropriate for this sort of management, which can complement silvicultural techniques when those are not adequate by themselves to achieve management goals.
- Oaks are not regenerating well in southern Wisconsin, especially on most mesic and dry-mesic sites, for numerous reasons. Because oak is still a dominant canopy species in many southern Wisconsin forests, there are opportunities to examine new regeneration techniques. Fire is being used as a tool along with other silvicultural techniques to regenerate oak in other states, and there are opportunities to adapt these techniques to Wisconsin. Oak regeneration on some sites requires high levels of disturbance, so sites may need to be selected with care. Excessive herbivory by white-tailed deer will be an additional challenge for many oak regeneration efforts, regardless of the techniques used.
- Silvicultural techniques can be used to maintain or restore compositional and structural diversity in southern Wisconsin's forests, including increasing the component of snags, large woody debris, and large trees to improve habitat for specialists dependent on these structural features.
- Forests older than 100 years continue to be become less common statewide. The southern forests offer opportunities to develop old-growth stands in natural community types not present in the north.
- Elms and butternuts have been severely diminished in importance due to diseases. Dutch elm disease-resistant American elm cultivars and hybrids now exist, and these could be planted to replace the lost trees (though there is an additional concern about loss of local genotypes). Germplasm is being collected from butternuts that appear to be surviving the fatal canker, and research is in progress to develop and propagate resistant strains.
- The negative impacts of invasive plant communities are great, but there are opportunities to reduce infestations through a variety of management techniques, including early detection, eradication, or control by mechanical, chemical, or biological means. Urban areas, where such problems can be especially severe, may have the benefit of a motivated citizenry, experienced land managers, and educational institutions that can provide critical information on invasive species control. Preventing the spread of invasive species to currently uninfested areas, especially those with high conservation value, is a major ecological priority for all of Wisconsin.

Other Opportunities

The remaining opportunities are broad in scale. These could have important impacts for southern forests and many other natural community types in Wisconsin.

- Negative impacts of herbivory in all ecological landscapes should be reduced by managing white-tailed deer populations at or below established goals wherever possible.
- Natural hydrologic regimes that have been altered by ditching, tiling, water control structures, or land clearing should be restored to benefit lowland forests such as Southern Hardwood Swamps, Floodplain Forest, and tamarack swamps. Adjoining uplands should be managed so that there is not excessive input of sediments or nutrients into wetlands.
- Efforts to address conservation priorities on private lands should be expanded. The Wisconsin DNR's Landowner Incentives Program (LIP) is assisting private landowners efforts in restoring and managing rare native grassland and savanna communities. Similar efforts could be used in forested communities to address conservation priorities not covered by existing programs.
- There are informational needs for both professional and lay audiences on complex ecological issues related to forest management and protection. For example, we still lack even basic life history information for some rare species.

Forested Areas with Major Conservation Opportunities

The following are examples of key areas of forest in southern Wisconsin that offer major conservation opportunities due to their condition, setting (context), size, scarcity of the embedded natural community types, and importance as connectors to other forests. See the 16 ecological landscapes chapters for more information about these areas.

- Baraboo Hills (mesic to dry upland forest types, including conifer "relicts")
- Kettle Moraine (dry types south, more mesic types north, conifer swamps)
- Kickapoo River valley (upland types, including both mesic and dry conifer "relicts")
- Wisconsin's Central Sands region (pine-oak forests, conifer swamps of tamarack-black spruce)

- Driftless Area forests (which have a relatively high percentage of forest cover, including northern relicts, steep environmental gradients leading to a diverse mosaic of communities, and broadscale planning opportunities)
- Lower Wisconsin River (lowland hardwood forest, upland bluff forest)
- Lower Chippewa River (lowland hardwood forest, upland bluff forest)
- Lower Black River (lowland hardwood forest, upland bluff forest)
- Mississippi River Bottomlands (lowland hardwood forest, upland bluff forest)
- Wolf River (lowland hardwood forest, tamarack)
- Yellow River Bottoms (lowland hardwood forest)
- Lower Lemonweir River (lowland hardwood forest)
- Cedarburg Bog (northern white-cedar swamp, ash swamp, upland hardwood forest)
- Milwaukee River corridor (lowland hardwood forest, upland hardwood forest)

Ecological Opportunities by Ecological Landscape

The best opportunities for the protection, restoration, and long-term conservation of southern forest communities at large scales are in the following ecological landscapes:

- Western Coulees and Ridges
- Central Sand Plains
- Southeast Glacial Plains
- Central Sand Hills

New Findings, Opportunities, and Conservation Needs

Planned and ongoing research, monitoring, and planning initiatives will help inform future ecosystem management efforts in Wisconsin. The following list highlights just a few of these projects.

- Resampling of the vegetation plots sampled by University of Wisconsin ecologist John Curtis 50 years ago revealed that there have been major changes to southern Wisconsin's forested natural communities in the last 50 years. In addition to a decline in oaks, there have been major changes to forest understories. Plant richness and heterogeneity have declined dramatically with rates of species loss almost double what has been observed in the northern part of the state (Rogers et al. 2008). These studies also underscore the importance of patch size and context for retaining native plant species in southern Wisconsin forests (Rogers et al. 2009).
- The public lands planning process for several major state properties has incorporated new information of the location and status of rare plants, rare animals, and significant natural communities (Glacial Heritage Area, Kettle Moraine State Forest, lower Chippewa River properties, Lower Wisconsin State Riverway, Columbia County properties, and others).
- The Driftless Area Initiative is working to educate legislators, landowners, and the public about important watershed and wildlife habitat issues within the Driftless Area.

Scientific names of species mentioned in the southern forest communities assessment.

Common name	Scientific name
Acadian Flycatcher[a]	*Empidonax virescens*
Adam-and-Eve orchid	*Aplectrum hyemale*
Alders	*Alnus* spp.
American basswood	*Tilia americana*
American beech	*Fagus grandifolia*
American bison	*Bos bison*
American chestnut	*Castanea dentata*
American Crow	*Corvus brachyrhynchos*
American elm	*Ulmus americana*
American mountain ash	*Sorbus americana*
Annosum root rot	*Heterobasidion annosum*
Asian longhorned beetle	*Anoplophora glabripennis*
Balsam fir	*Abies balsamea*
Big-tooth aspen	*Populus grandidentata*
Bishop's cap	*Mitella diphylla*
Bitternut hickory	*Carya cordiformis*
Black bear	*Ursus americanus*
Black cherry	*Prunus serotina*
Black locust	*Robinia pseudoacacia*
Black oak	*Quercus velutina*
Black spruce	*Picea mariana*
Black walnut	*Juglans nigra*
Black willow	*Salix nigra*
Black-and-white Warbler	*Mniotilta varia*
Blue ash	*Fraxinus quadrangulata*
Blue cohosh	*Caulophyllum thalictroides*
Blue Jay	*Cyanocitta cristata*
Bluebead lily	*Clintonia borealis*
Blueberries	*Vaccinium angustifolium*
Blueberries	*Vaccinium myrtilloides*
Bluestem goldenrod	*Solidago caesia*
Blue-winged Warbler	*Vermivora cyanoptera,* listed as *Vermivora pinus* on the Wisconsin Natural Heritage Working List
Bobcat	*Lynx rufus*
Bracken fern	*Pteridium aquilinum*
Brown-headed Cowbird	*Molothrus ater*
Bur oak	*Quercus macrocarpa*
Butternut	*Juglans cinerea*
Buttonbush	*Cephalanthus occidentalis*
Canada Warbler	*Cardellina canadensis,* listed as *Wilsonia canadensis* on the Wisconsin Natural Heritage Working List
Canada yew	*Taxus canadensis*
Cardinal flower	*Lobelia cardinalis*
Cerulean Warbler	*Setophaga cerulea,* listed as *Dendroica cerulea* on the Wisconsin Natural Heritage Working List
Common buckthorn	*Rhamnus cathartica*
Cottonwood	*Populus deltoides*
Cougar	*Puma concolor*
Crow	*Corvus brachyrhynchos*
Dutch elm disease fungus	*Ophiostoma ulmi*
Dutchman's breeches	*Dicentra cucullaria*
Eastern hemlock	*Tsuga canadensis*
Eastern massasauga rattlesnake	*Sistrurus catenatus catenatus*
Eastern red bat	*Lasiurus borealis*
Eastern red-cedar	*Juniperus virginiana*
Eastern white pine	*Pinus strobus*

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Scientific names of species, continued.

Common name	Scientific name
Elk	*Cervus elaphus*
Emerald ash borer	*Agrilus planipennis*
Enchanter's nightshade	*Circaea lutetiana*
False rue anemone	*Isopyrum biternatum*
False Solomon's seal	*Smilacina racemosa*
Fisher	*Martes pennanti*
Forked aster	*Aster furcatus*
Four-toed salamander	*Hemidactylium scutatum*
Garlic mustard	*Alliaria petiolata*
Glossy buckthorn	*Rhamnus frangula*
Golden-winged Warbler	*Vermivora chrysoptera*
Gray dogwood	*Cornus racemosa*
Gray wolf	*Canis lupus*
Green ash	*Fraxinus pennsylvanica* var. *subintegerrima*
Green dragon	*Arisaema dracontium*
Green-headed coneflower	*Rudbeckia laciniata*
Gypsy moth	*Lymantria dispar*
Hackberry	*Celtis occidentalis*
Hazelnut	*Corylus americana*
Honey locust	*Gleditsia triancanthos*
Honeysuckle	*Lonicera morrowii*
Honeysuckle	*Lonicera tatarica*
Hooded Warbler	*Setophaga citrina,* listed as *Wilsonia citrina* on the Wisconsin Natural Heritage Working List
Interrupted fern	*Osmunda claytoniana*
Ironwood	*Ostrya virginiana*
Jack pine	*Pinus banksiana*
Japanese barberry	*Berberis thunbergii*
Kentucky coffee tree	*Gymnocladus dioicus*
Kentucky Warbler	*Geothlypis formosa,* listed as *Oporornis formosus* on the Wisconsin Natural Heritage Working List
Lady fern	*Athyrium filix-femina*
Lopseed	*Phryma leptostachya*
Louisiana Waterthrush	*Parkesia motacilla*, listed as *Seiurus motacilla* on the Wisconsin Natural Heritage Working List
Mayapple	*Podophyllum peltatum*
Moneywort	*Lysimachia nummularia*
Moonseed	*Menispermum canadense*
Mountain maple	*Acer spicatum*
Multiflora rose	*Rosa multiflora*
Nodding pogonia	*Triphora trianthophora*
Northern flying squirrel	*Glaucomys sabrinus*
Northern white-cedar	*Thuja occidentalis*
Norway maple	*Acer platanoides*
Norway spruce	*Picea abies*
Oriental bittersweet	*Celastrus orbiculatus*
Passenger Pigeon	*Ectopistes migratorius*
Pileated Woodpecker	*Dryocopus pileatus*
Pipsissewa	*Chimaphila umbellata*
Poison ivy	*Toxicondendron radicans*
Poison sumac	*Toxicondendron vernix*
Prothonotary Warbler	*Protonotaria citrea*
Quaking aspen	*Populus tremuloides*
Raccoon	*Procyon lotor*
Red elm	*Ulmus rubra*

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Scientific names of species, continued.

Common name	Scientific name
Red maple	*Acer rubrum*
Red oak	*Quercus rubra*
Red pine	*Pinus resinosa*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Red-shouldered Hawk	*Buteo lineatus*
Reed canary grass	*Phalaris arundinacea*
River birch	*Betula nigra*
Scots pine	*Pinus sylvestris*
Sedges	*Carex* spp.
Shagbark hickory	*Carya ovata*
Silver maple	*Acer saccharinum*
Silver-haired bat	*Lasionycteris noctivigans*
Snow trillium	*Trillium nivale*
Spring beauty	*Claytonia virginica*
Striped skunk	*Mephitis mephitis*
Sugar maple	*Acer saccharum*
Swamp white oak	*Quercus bicolor*
Sycamore	*Platanus occidentalis*
Tamarack	*Larix laricina*
Tick-trefoil	*Desmodium glutinosum*
Tick-trefoil	*Desmodium nudiflorum*
Timber rattlesnake	*Crotalus horridus*
Toothwort	*Dentaria laciniata*
Touch-me-not	*Impatiens biflora*
Trilliums	*Trillium* spp.
Trout lily	*Erythronium albidum*
Trout lily	*Erythronium americanum*
Twining hog-peanut	*Amphicarpaea bracteata*
Violets	*Viola* spp.
Water-willow	*Decodon verticillatus*
White ash	*Fraxinus americana*
White birch	*Betula papyrifera*
White mulberry	*Morus alba*
White oak	*Quercus alba*
White spruce	*Picea glauca*
White-tailed deer	*Odocoileus virginianus*
Wild cucumber	*Echinocystis lobata*
Wild ginger	*Asarum canadense*
Wild grape	*Vitis riparia*
Wild Turkey	*Meleagris gallopavo*
Wintergreen	*Gaultheria procumbens*
Wood frog	*Rana sylvatica*
Wood nettle	*Laportea canadensis*
Wood Thrush	*Hylocichla mustelina*
Wood turtle	*Glyptemys insculpta*
Woodbine	*Parthenocissus vitacea*
Woodland jumping mouse	*Napaeozapus insignis*
Woodland phlox	*Phlox divaricata*
Woodland vole	*Microtus pinetorum*
Worm-eating Warbler	*Helmitheros vermivorum*, listed as *Helmitheros vermivorus* on the Wisconsin Natural Heritage Working List
Yellow birch	*Betula alleghaniensis*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologist Union.

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Wetland Communities

Wetland communities, whether dominated by trees, shrubs, or herbs, have a common characteristic: their soils are at least periodically saturated or covered by water. This is reflected in the legal definition of a wetland in Section 23.32(1) of the Wisconsin Statutes: "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or ***hydrophytic vegetation*** and which has soils indicative of wet conditions." Wetlands form where the topography is conducive to retaining water, including flat areas or depressions with limited outflow, where groundwater seepage or discharge is present at the land surface, where groundwater periodically saturates the soil, and in floodplains with water flow-through. Wetlands can sometimes form in unlikely places, such as on slopes when the local climate produces continually wet conditions (Verry 1988) or where groundwater seepage or discharge occurs.

Community Description

A variety of influencing factors leads to many different kinds of wetland communities. Water quality, quantity, periodicity, and chemistry are the major determinants of ecological development in wetlands (Verry 1988). These characteristics of water are often related to climate, topography and landscape position, bedrock geology, depth to bedrock, soils, and past and present land uses.

The names of wetland community types reflect their diversity: Wet-mesic Prairie, Southern Hardwood Swamp, Open Bog, Calcareous Fen, Northern Sedge Meadow, Shrub-carr, Emergent Marsh, and Alder Thicket, among others. Most of these community types were described by Curtis (1959). Since then, some revisions have been made and additional types described by staff of the Wisconsin Natural Heritage Inventory (NHI). For detailed descriptions of all of these community types see Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin."

Wetland communities include the following major types:

- Marshes, including emergent, submergent, and floating-leaved types, are found in shallow water basins and at the edges of lakes and streams. Marshes are inundated permanently or for prolonged periods of time.
- Wet meadows, which include sedge meadows, wet prairies, herb-dominated fens, and some surrogate grasslands, develop on permanently saturated soils and are composed of grasses, sedges, rushes, other graminoid plants, and many wetland forbs.
- Peatlands are characterized by the accumulation of organic matter, which is produced and deposited more rapidly than it is decomposed, leading to peat formation. This process is more likely to occur in cold climates where decomposition is slow. Peatlands include two wetland types that are usually defined separately:

Southern Sedge Meadow, dominated by tussock sedge and Canada bluejoint grass. White River Marsh State Wildlife Area, Green Lake County. Photo by Eric Epstein, Wisconsin DNR.

Extensive Emergent Marsh within Great Lakes estuary complex. This site is now part of a National Estuarine Research Reserve. St. Louis River, Douglas County. Photo by Eric Epstein, Wisconsin DNR.

A vast boggy peatland fills part of the bed of extinct Glacial Lake Wisconsin. Sphagnum mosses and sedges are dominant in this view. Bear Bluff, Jackson County. Photo by Eric Epstein, Wisconsin DNR.

- Bogs form in closed basins or on slopes where the only water sources are precipitation and limited surface runoff; they typically have low nutrient status. The peat is acidic, formed from decomposed sphagnum mosses and other vegetation. Bogs were once thought to be a successional stage between open lake and forest in which the peat mat would build up and be colonized by shrubs and eventually trees. We now know that bogs can persist in nearly the same condition for thousands of years (WCMP 1995).
- Fens also form in basins and on slopes, but groundwater inflow is present in addition to water inputs from surface runoff and precipitation. Fens are less acidic and receive greater amounts of oxygen and nutrients because of groundwater contributions. Different types of fens develop under different nutrient conditions and are dependent on the composition of the glacial materials and soils through which the water flows. Calcareous Fens occur where dolomite bedrock or calcareous glacial tills contribute high levels of calcium and magnesium bicarbonates to the groundwater. Open fens support grasses, sedges, and a diverse assemblage of other herbaceous plants. Peats that accumulate in fens are less acidic than those in bogs and can even be alkaline (Curtis 1959, Verry and Boelter 1978).

This alkaline pond is ringed with open, shrubby, and forested peatlands. These are fens, not bogs. Unnamed pond on the Door Peninsula, Door County. Photo by Eric Epstein, Wisconsin DNR.

- Shrub swamps are wetlands dominated by tall shrubs such as alders (*Alnus* spp.), willows (*Salix* spp.), or dogwoods (*Cornus* spp.). They may dominate wetlands on some sites for long periods of time (centuries), occur as a successional stage that follows dominance by herbaceous vegetation (sedge meadows, fens, or wet prairies), or precede eventual dominance by trees. Shrubs may temporarily dominate heavily logged or otherwise disturbed lowland forests.
- Forested wetlands may be dominated by either conifers or hardwoods or by various mixtures of tree species from both groups. Forested wetlands occur on alluvial soils in river floodplains or on periodically saturated or inundated sites on former lakebeds or other low-lying poorly drained landscape features throughout the glaciated parts of Wisconsin.

Global/Regional Context

When the glaciers retreated approximately 10,000 years ago, much of Wisconsin and the upper Great Lakes region were left with an abundance of wetlands. It is estimated that the number of wetland acres in Wisconsin prior to Euro-American settlement, although not precise, was about 10 million acres (or roughly 29% of the state) (WDNR 2012c). Today, only about half that number of wetland acres remains. The abundance of wetlands in Wisconsin makes them important in helping to sustain many populations of North American wetland species, including mammals, herptiles, breeding and

*Shrub-carr is the most common and characteristic tall shrub-dominated wetland community in southern Wisconsin. This stand along the Milwaukee River within the Kettle Moraine State Forest – North Unit is composed mostly of willows, dogwoods, and viburnums (*Viburnum *spp.). Scattered tamarack are present. Fond du lac County. Photo by Eric Epstein, Wisconsin DNR.*

Older floodplain forests provide critical habitat for many rare species, such as Prothonotary Warbler and Red-shouldered Hawk. This stand is dominated by large silver maple and green ash occurs along the lower Chippewa River at Tiffany Bottoms State Natural Area, Buffalo County. Photo by Eric Epstein, Wisconsin DNR.

Scattered black spruce and tamarack increase in density around this northern Wisconsin lake to form a dense acid conifer swamp. The open area in the foreground would be classified by many wetland ecologists as a "Poor Fen," based on peat landform, groundwater pH, and characteristic plant species indicators. Photo by Eric Epstein, Wisconsin DNR.

migrating birds, spawning fish, and invertebrates. For example, a large proportion of the Canvasback (*Aythya valisineria*) and Tundra Swan (*Cygnus columbianus*) populations use the Mississippi River wetlands as staging areas during migration. Two Wisconsin wetlands have been declared "wetlands of global significance" by the Ramsar Convention on Wetlands of International Importance (a 1971 international treaty adopted in the Iranian city of Ramsar for the conservation of wetlands): the Kakagon and Bad River Sloughs and Horicon Marsh. Horicon Marsh, at over 30,000 acres, is considered the largest cat-tail marsh in North America. It supports huge numbers of resident and migratory birds, including species that are rare or declining.

As of 1992, 43% of all federally listed threatened and endangered species in the United States used wetlands at some point in their life cycles (Feierabend 1992). For Wisconsin, the Natural Heritage Inventory does not differentiate between listed species that are wetland dependent and those that are dependent on lakes and streams but not wetlands. However, of the 325 listed endangered and threatened plants and animals, 128 are dependent on wetlands, open waters, or both (L. Kitchel, Wisconsin DNR, personal communication; M. Miller, Wisconsin DNR, personal communication).

There are some wetland types in Wisconsin that are rare and have regional and global importance. Some of the largest and least disturbed examples of freshwater estuaries occur on Wisconsin's Great Lakes shores, especially along southwestern Lake Superior. In recognition of the importance of these Great Lakes coastal wetlands, a National Estuarine Research Reserve has been established on the lower St. Louis River at the western end of Lake Superior by the National Oceanic and Atmospheric Administration and many public and private partners.

As Great Lakes water levels dropped at the end of the Pleistocene, complex coastal ridge-and-swale landforms were created, especially along Lake Michigan. These now feature diverse mosaics of natural communities, which in turn support many rare species—some of them, such as dwarf lake iris (*Iris lacustris*), are endemic to the shores of the Great Lakes. Chiwaukee Prairie (Kenosha County) is the southernmost of these coastal ridge-and-swale sites in Wisconsin. The vegetation there includes excellent examples of exceptionally diverse tallgrass prairie, sedge meadow, marsh, and fens.

Other wetland communities of regional or continental significance because of their rarity, extent, and condition are the remnant Wet and Wet-mesic Prairies, Calcareous Fens, and sedge meadows of interior southern Wisconsin, the extensive Floodplain Forests flanking the state's largest rivers, and the numerous forested and open peatlands of northern Wisconsin. Extremely rare wetland communities of local distribution include rare types such as Coastal Plain Marsh and White Pine-Red Maple Swamp. Both of these communities support wetland-dependent plants and animals that are now of conservation concern.

Current Assessment of Wetland Communities

Assessing wetland communities includes identifying their extent and distribution across the landscape as well as evaluating the health and diversity of the plant and animal species of which they are composed. In addition, documenting the condition and degree of disturbance to wetlands, the trends in the gains or losses of wetland acres, and the changes in the ecological composition, structure, and function of wetlands are important.

Distribution of Wisconsin Wetland Types

Wetlands cover about 16% of Wisconsin's surface area and are noted for their abundance of distinctive plant and animal life. Wetlands are typically interspersed among other community types, affecting and affected by adjacent plant communities, aquatic features, and other cover types.

Forested wetlands occur throughout Wisconsin and are part of the continuum of northern or southern forest ecosystems and forest community types. Wetlands are also interspersed among the formerly extensive prairie and oak savanna areas of southern and east central Wisconsin (these are usually, although not exclusively, marshes, sedge meadows, fens, or wet prairies). In the Driftless Area of southwestern Wisconsin (which, while not overridden by continental glaciers, was impacted in some areas by glacial meltwater), the distribution, extent, and types of wetlands present are dictated by landform, bedrock, and hydrology. Wetlands in southwestern Wisconsin exist primarily along rivers and streams and in areas receiving spring seepage. In northern and central Wisconsin, wetlands occur on vast areas of organic peat soils occupying former glacial lakebeds; as bogs, northern fens, and sedge meadows; along streams and rivers; on the borders of lakes; as forested swamps and bottomlands; and as coastal wetlands along the dynamic shores of the Great Lakes. Some wetlands occur in large continuous patches (especially the peatland types), while others are inclusions within extensive areas of upland forest. Some of these, such as ephemeral ponds, are very small, but even these provide ***critical habitat*** for many species and contribute to the health of the surrounding forests in many ways.

National Wetland Status

Wetland loss and degradation of wetland quality are the most serious problems affecting wetland communities in Wisconsin and across the country. Over half of the original wetland acreage in the conterminous U.S. has been lost since Euro-American settlement (Feierabend 1992). A periodic federal report on wetlands status and trends has kept track of wetland losses and gains over multi-year blocks of time, and the most recent reports show that the nationwide trend of wetland losses has been slowing somewhat over time.

- 1986–1997: There was an estimated net loss of 644,000 wetland acres (Dahl 2000). While that figure is large, this represents an 80% reduction in the rate of loss compared to the previous decade. This reduction was due in significant part to participation in agricultural set-aside programs. In 1997 the remaining freshwater wetland area in the U.S. was approximately 102.23 million acres.
- 1998–2004: There was a net gain of 220,000 freshwater wetland acres (Dahl 2006). This gain is believed to be the result of federal programs to restore and "create" wetlands. However, about 56% of all created wetlands were ponds of lower biodiversity and lower ecological value than the former natural wetlands they were intended to replace. During this period, there was a net loss of 495,000 acres of vegetated wetlands. This included a loss of 900,000 acres of natural shrub wetland that was partially offset by "creation" of wetlands of often lesser value elsewhere. The 1998–2004 wetlands status and trends report concluded that there were an estimated 102.45 million acres of wetlands nationally, which represented the first period of wetland increase since tracking began in the 1950s.
- 2004–2009: The nation lost another 185,000 acres of natural freshwater wetland, which was offset by the creation of 207,000 acres of wetlands classified as ponds (again, of limited or unknown ecological value) (Dahl 2011). These 2009 data documented the presence of 104.27 million freshwater wetland acres, an increase of almost 22,000 acres over the previous period.

Diverse complex of open, shrubby, and forested wetlands associated with the confluence of two headwaters streams. Surrounding uplands are forested. Hydrology is intact, and water quality remains good. Edge of the Bloomer Moraine, Chippewa County. Photo by Eric Epstein, Wisconsin DNR.

Despite the increase in overall acreage of freshwater wetlands, naturally occurring freshwater wetlands continue to be lost in the conterminous U.S. Causes of wetland losses nationally were attributed to urban development, agriculture, silviculture, and rural development (Dahl 2011). Most of the losses due to silviculture occurred in the southeastern U.S., where ditching and partial drainage are used in the process of converting wetlands to commercial forests (T. Dahl, National Wetlands Inventory, personal communication).

National wetland inventories therefore show a slowdown in the rate of loss of naturally occurring wetlands and an overall net gain in wetland area. However, looking only at trends in wetland area does not provide a full picture of the status of wetlands in the U.S. Most losses of naturally occurring wetlands are essentially permanent, such as losses from urban development and roads. Unfortunately, most of the recent wetland "gains" are ponds (such as those created expressly for storm water treatment and edged with some wetland vegetation), which do not replace much of the lost natural wetland ecological functions. Other wetland gains may include lands with wet or saturated soils, but these may support a totally different flora from what had occurred on these sites before they were altered. In addition, many restored or recreated wetlands are vegetated with very small numbers of native plants, and some are entirely dominated by exotic plants, some of which may be invasive.

Assessing these sorts of losses of wetland quality and function across the U.S. is therefore much more complicated than simply compiling acreage tallies. Instead, current wetland regulatory programs are focusing on the restoration of wetlands that have a reasonable degree of hydrologic function and a measure of floristic diversity that can provide valuable habitat and help deter invasion by nonnative species.

Midwest Wetland Status

The National Resources Inventory (NRI) compiled wetlands information for the Midwest region, including the states of Minnesota, Wisconsin, Michigan, Iowa, Missouri, Illinois, Indiana, and Ohio, and found that between 1992 and 1997 there was a net loss of approximately 25,800 acres in this region (USDA 2000). The net loss estimate is based on gross losses of 74,200 acres and gross gains of 48,400 acres through wetland restoration and replacement. Of gross loss estimates, 38,500 acres were attributed to agriculture, 21,300 acres to

Ditched meadow near the city of Superior. Photo by Eric Epstein, Wisconsin DNR.

Spoil banks along this channelized creek have been colonized by box elder (Acer negundo)*, an opportunistic and weedy native species. The adjoining wetlands are entirely dominated by the highly invasive and nonnative reed canary grass. Though much of what is pictured is still classified as wetlands, this highly disturbed site has lost many of its functional values. Dell Creek, Sauk County. Photo by Eric Epstein, Wisconsin DNR.*

development, and 14,300 acres to silviculture. The NRI estimates in the silviculture category are believed to include an indeterminate acreage of losses of forested wetland not related to forestry operations, such as from the effects of urbanization (S. Brady, National Resources Inventory, personal communication). Federal wetlands data show that for the period from 1997 to 2007, there was a net increase of 44,500 acres in area classified as wetland (USDA 2009).

Wisconsin Wetland Status

Assessing the status of wetlands in Wisconsin relies heavily on the Wisconsin Wetland Inventory (WWI) as well as field surveys that provide documentation of wetland conditions. The Wisconsin DNR completed the initial WWI for all counties in the state in 1984, using aerial photography obtained in 1978–79. The first wetlands inventory delineated and classified wetlands using polygon sizes of 2 to 5 acres or larger. Updates since 1984 delineate areas as small as possible based on more recent 1:20,000-scale stereo aerial photographs (Figure 2.21). As of 2000, Wisconsin wetlands acreage was recorded as 5,331,392 acres (Hagen 2008).

As of 2011, Marathon County is the last county for which the WWI wetland figures are based on the old aerial photography obtained in 1978–79. For the other 71 counties, the WWI was updated from aerial photos taken between 1988 and 2011. As of 2012, updates have been completed for most counties to improve mapping accuracy, especially in the northern counties where interpretation of initial photos was previously difficult due to the use of leaf-on photos, which obscured some wetland types. Also, wetlands that were being farmed in 1978–79 were not included as part of the original WWI but are now being mapped. It is important to note that wetland acreage figures are never precise because of yearly changes in those agriculturally modified wetlands that are put into or taken out of agricultural production and also because of natural fluctuations in lake and stream levels. Digital maps are available for all but six counties (in west central and northeastern Wisconsin) whose wetland acreage is available as paper maps only.

In addition, state data from the 2007 NRI are now available for Wisconsin (USDA 2009). Additional information regarding wetland and wetland losses in Wisconsin may be requested from the State Resource Inventory Specialist, USDA, Natural Resources Conservation Service.

Wisconsin's wetland status is similar to that of the nation as a whole; about 47% of the state's approximately 10 million acres of wetland were lost between 1780 and 1979 (WDNR 2012c). These losses were primarily due to drainage for agriculture. However, wetlands along major rivers such as the Fox, Wisconsin, and Mississippi and the bays of the Great Lakes have been developed for port facilities and for industries that require water for transport, cooling, or processing. Some communities have used wetlands as sites for waste discharge, marinas, wharfs, or residential developments. Deposition of dredged materials has been a factor in some

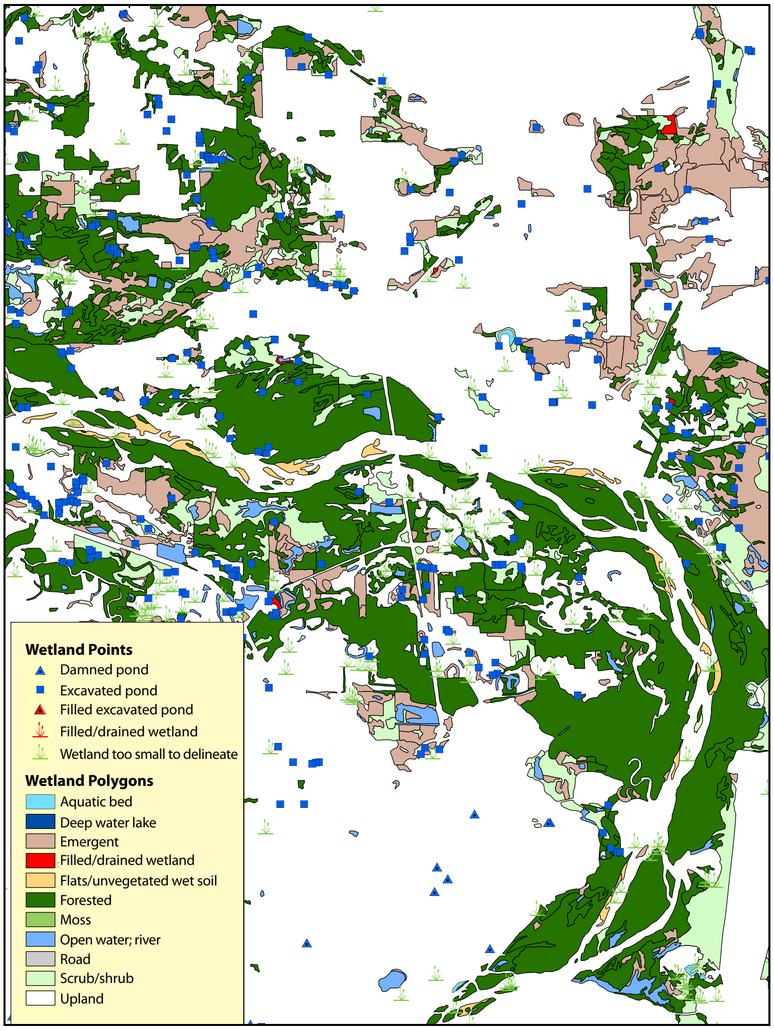

Figure 2.21. *Wisconsin Wetland Inventory maps are a graphic depiction of the type, size and location of wetlands in Wisconsin. Compiled from high altitude imagery, soil surveys, and field work, maps at the scale of 1:24,000 (1 inch = 2,000 feet) are very useful as a guide for planning purposes.*

wetland loss or degradation. About 5.3 million acres of wetlands currently exist in Wisconsin, and these are most concentrated in the central and northern parts of the state.

Wetlands continue to be filled for development, although the rate has slowed during the past decade (WDNR 2012c). This loss is at least partially offset by wetland restoration elsewhere. A Wisconsin DNR review of U.S. Army Corps of Engineers (USACE) individual and nationwide permit decisions from August 1991 through April 1998 documents wetland losses of approximately 2,053 acres statewide (312 acres per year on average). This represents a 460% decline in annual wetlands losses compared to the period from 1982 to 1991, which saw permitted wetland losses of 1,128 acres to as much as 1,400 acres per year on average (WSN 2001). From 2001 to 2008, average annual permitted wetlands losses declined further, to less than 100 acres per year. This decline coincided with the adoption of state wetland water quality standards on August 1, 1991 (Cain 2008). These wetland acreage figures are estimates only and do not reflect total wetland loss for this time period. Wetland losses due to illegal wetland filling, wetland drainage, and activities pre-authorized by general and nationwide permits are not known for this time period, and it is likely that some USACE wetland permit decisions were missed during the initial review. In addition to permitted wetland loss, unauthorized wetland filling is believed to be occurring, but the rate is unknown (WDNR 2012c). The percentage of loss attributable to the different kinds of agriculture, urban, and industrial development is unknown.

Many of Wisconsin's remaining wetlands are now in an altered or disturbed condition due to partial drainage, encroachment by invasive species, vegetation clearing, grazing, periodic plowing, and other agricultural activities. Wetlands have also been degraded by hydrologic changes, erosion, sedimentation, and eutrophication. Poor water quality brought about by agricultural, transportation, or urban-industrial land uses can affect the floristic composition of wetlands and cause sensitive plants and associated animals to decline or be lost. Altered hydrology may result in complete loss of wetlands if urbanization or other developments diminish groundwater recharge or surface water inputs. In some cases, dam and dike construction and discharge or redirection of storm water can result in conversion of vegetated wetlands to open water areas. The "Wetlands Regulatory Reform Act," passed in 2012, has left concerns that its loosening of alternatives analysis and mitigation requirements will result in unnecessary wetlands losses (Bochert 2012).

Wetland "enhancement" projects can result in a net loss of diversity when existing wetlands of one type are converted to wetland vegetation of another type. This is especially true when the converted wetland type is rare and/or provides habitat for specialized organisms that are lost due to the conversion. Ecological restoration of damaged or lost wetlands is expensive and difficult to accomplish since the previous physical and biotic environmental conditions are difficult if not impossible to replicate completely. Many wetland enhancement and restoration projects face significant problems created by the colonization and spread of invasive plant species.

There is currently no detailed assessment of wetland conditions that fully describes the extent and importance of the different factors impacting wetlands. The Wisconsin DNR's Bureau of Watershed Management has noted that the integrity of some wetlands is being affected by agricultural drainage, runoff pollution, alteration of water flows in the watershed, and loss of connections to quality upland habitat (Hagen 2008). Still, there are many wetlands in the state that are comparatively free of such disturbances. The Wisconsin Natural Heritage Inventory tracks, describes, and ranks the occurrences of relatively undisturbed examples of all wetland community types native to Wisconsin.

The Wisconsin DNR's Wetland Restoration Tracking Database, federal Conservation Reserve Program data, ***Wetland Reserve Program*** enrollments, and other information enables the Wisconsin DNR to monitor and report on positive and negative wetlands impacts in the state. A recent report based on these data (WDNR 2008) indicated that in 2006 and 2007 there was a cumulative total of 6,855 acres of wetland restoration and enhancement in the state, which amounts to 0.1% of the estimated 4.7 million acres of wetlands lost in Wisconsin since Euro-American settlement. About 75% of these positive benefits resulted from re-establishment of formerly drained wetlands, while 25% represented the enhancement of existing wetlands Successful projects include restoration of wetlands along the Lake Superior shore, at Avon Bottoms along the lower Wisconsin River, and at the Pheasant Branch Conservancy in Dane County. Cumulative negative impacts to wetlands for 2006 and 2007 totaled 1,906 acres. Four hundred seven acres were lost through permitted fill, with road projects accounting for over half that amount. The remaining 1,498 acres were impacted by permitted construction work in existing wetlands, primarily in utility corridors. These impacted acres retained most or all of their wetland functions and are considered to be "acreage neutral."

Illegal fill, legal drainage for agriculture (which appears to be increasing for production of high-value crops), and storm water and wastewater discharges are not entered into

Wisconsin must play a major role in the conservation of the globally rare and federally endangered Hine's emerald dragonfly (Somatochlora hineana). *Several of this species' most important known breeding sites are alkaline wetlands on the Door Peninsula. Photo by Kathryn Kirk, Wisconsin DNR.*

The swamp metalmark (Calephelis muticum) *(Wisconsin Endangered) is a globally rare butterfly that is strongly associated with calcareous fens. Only a few populations of this species persist in Wisconsin. Marquette County. Photo by William Bouton.*

Eastern massasauga rattlesnake (Sistrurus catenatus)*, a wetland species that is now extremely rare in Wisconsin. It is Wisconsin Endangered, and the U.S. Fish and Wildlife Service has listed it as a candidate for the federal threatened and endangered species list. Photo by Rori Paloski, Wisconsin DNR.*

Wilson's Phalarope (Phalaropus tricolor) *(Wisconsin Special Concern) is a rare breeding bird in Wisconsin, where it inhabits pools and small ponds within extensive marshes and sedge meadows. Photo by Dominic Sherony.*

the available database and are therefore not tracked. Based on wetlands violations recorded in 2008, Wisconsin DNR staff are concerned that illegal wetland filling is increasing, especially in northern Wisconsin counties. However, some wetland enhancement projects by private landowners, such as controlled burns and efforts to control invasive species, also cannot be reliably tracked.

Wisconsin DNR staff evaluate the functional values of wetlands, as identified in Wisconsin's Water Quality Standards for Wetlands, Chapter NR 103, Wisconsin Administrative Code (see the "Laws" section below), as one factor in assessing state wetland status. This evaluation helps document how certain regulated activities affect individual wetlands. The Wisconsin DNR has developed a rapid assessment methodology to standardize the evaluation procedure.

After an absence of almost a century, a self-sustaining population of the Trumpeter Swan (Cygnus buccinator) *has been restored to Wisconsin in recent decades. Photo by Wisconsin DNR staff.*

In parts of central Wisconsin, a high water table has persisted in spite of efforts to drain the area. Complex patterns of sandy ridges (some of them ancient sand dunes) interspersed with boggy, sedge-dominated peatlands still exist where the hydrology has been relatively unmodified by ditches, dikes, or dams. Necedah National Wildlife Refuge, Juneau County. Photo by Eric Epstein, Wisconsin DNR.

Examples of activities that may affect individual wetlands include wetland fills for urban development or roads, storm water or wastewater discharges, landfill expansions, logging operations, and Wisconsin DNR management activities. Functional values assessed include floral integrity; fish and wildlife habitat; flood protection; water quality protection; shoreline protection; groundwater recharge and discharge; recreational, cultural, educational, and scientific values; and natural scenic beauty.

Issues of Composition, Structure, and Function

The composition, structure, and function of wetland communities are dependent on many factors, including the hydrology, topography, soils, bedrock geology, climate, and past and present land uses.

Composition

Wetlands vary in their plant and animal composition, vegetative structure, and diversity of physical and chemical attributes. Northern bogs, for example, are highly acidic and support very different plant and animal species than the nutrient-rich, more alkaline marshes, meadows, and fens of southern Wisconsin. Both northern and southern wetlands have significant conservation values unique to their regions and to the plant and animal life adapted to them. (See Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin.")

Issues affecting the composition of wetlands in Wisconsin include many factors such as surrounding land use, altered hydrology, water quality, invasive species, and more. Invasive species such as purple loosestrife (*Lythrum salicaria*), common reed (*Phragmites australis*), and glossy buckthorn can outcompete and replace native vegetation, simplifying plant composition. Common carp (*Cyprinus carpio*) can destroy native submergent vegetation and suspend sediments in the water column, shading out native aquatic plants and preventing them from surviving. Altered hydrology (either reducing or increasing water levels, disrupting natural water level fluctuations necessary to sustain some organisms over time, or changing the amount or timing of water reaching a wetland) can change plant species composition. Water quality degradation caused by urban and agricultural runoff can prevent native species from surviving and encourage the establishment and expansion of invasive species. Converting wetlands from one type to another (e.g., converting sedge meadows to deep-water marshes) can eliminate sensitive native plant communities and the animals that depend on them.

Structure

Wetland community structure is a reflection of various environmental characteristics and external influences such as land use and natural disturbance. Location on the landscape, hydrological influences, water chemistry, characteristics of surrounding uplands, and other factors influence the structure of the plant community of a wetland. Wetland structure therefore can vary widely from an open growth of mosses, sedges, and low shrubs, to dense patches of tall shrubs, to thick stands of trees such as tamarack and black spruce.

Factors affecting the plant composition of wetlands also influence the structure of wetland vegetation. Changing hydrology can convert an open wetland to a shrub swamp (e.g., with decreasing water levels) or a forested wetland to an open wetland (e.g., with increasing water levels). Changing plant composition caused by degraded water quality or the spread of invasive species can change the structure of wetland vegetation from a native community with interspersed open water to a closed vegetative community with little or no open water or completely open water. Lack of fire in some wetland communities allows them to change from open wetlands to shrub- or tree-dominated wetlands. Wetland conversion can cause structure to change from dominance by vegetation to unvegetated open water.

Function

Wetlands benefit the ecology of the state through many ecological functions that are easy to take for granted. They provide critical habitat for wildlife and provide a buffer between uplands and surface waters. They trap sediment and pollutants, remove nutrients, protect shorelines, store water, prevent or ameliorate flooding, and moderate the impacts of droughts, factors that also often protect water quality and quantity (WASAL 2003, Goosen and Villinga 2004). Wetlands also serve as both discharge and recharge areas for groundwater, and in some wetland communities, they sequester carbon in the organic soils that form beneath them. As noted earlier, the Wisconsin DNR uses a rapid assessment method for recording what these functional values are for any given wetland area (in addition to some social and economic values). Different wetlands perform different functions, a phenomenon noted even between two wetlands that may at first appear similar.

Ecological functions in wetlands are sometimes different from those of upland communities. For example, for all but shallow inland wetlands, succession can be so slow that it is almost imperceptible, being based on accumulation of organic material over time (except where catastrophic disturbance or human activities have caused rapid changes). On the other hand, wetland community structure can be set back or maintained due to the scouring of streamside wetlands by flooding, rather than the wetland community changing and developing into something else over time. By contrast, a community such as a grassland or barrens can succeed to a young forest in a few decades in the absence of periodic fire or other natural disturbance.

The spatial arrangement of wetlands is one factor that makes them a key habitat or habitat component for many wildlife species. Wetlands can serve as vital corridors, linking aquatic and upland areas, as they may be found within upland forests, savannas, barrens, and prairies. This spatial pattern of wetland occurrence helps them provide water, food, and shelter for many wildlife species and supply unique habitat conditions for many plant species.

Migratory waterfowl use wetlands to find food, resting places, breeding habitat, and other seasonal habitats (Stearns 1978). For example, of Wisconsin's 370 species of birds, 39% live in or make significant use of wetlands (L. Kitchel, Wisconsin DNR, personal communication). Wetlands also play an essential role in sustaining productive fisheries as spawning and nursery areas (GLIN 2010). Wetlands support many resident and migratory species from other wildlife groups, including reptiles, amphibians, and invertebrates, which perform many ecological roles, including serving as a critical food base for other species.

Within a wetland, the heterogeneity of microhabitats contributes to the occupancy by specialists; for example, different moss species may be restricted to specific heights on the sides of hummocks in a northern fen (Crum 1988).

Wetlands have high rates of productivity when compared with other types of ecosystems, allowing them to support an abundance of plant and animal life. Also, movement of nutrients, organic matter, and propagules (cuttings, seeds, spores, etc.) through the system can often take place in water. This mobility contributes to food web relationships that are unlike those of uplands where producers, consumers, and decomposers may be spatially separate (Darnell 1978).

Factors affecting the function of wetlands are similar to the issues affecting the composition and structure of wetlands. Surrounding land use, changing hydrology, water quality degradation, invasive species, and type conversion all affect the ecological functioning of wetlands for the reasons described in the "Composition" and "Structure" sections above and in the "Land Use and Changes in Wetland Function" section below.

Land Use and Economic Considerations

Major issues that should be considered when planning for wetland protection and management are described below. The degree of protection given to Wisconsin's wetlands is determined by a mix of federal and state laws and in some cases by local government regulations and private land trusts. However, activities far from wetlands that may not be under the jurisdiction of wetland regulation can have negative impacts on wetlands, creating unforeseen costs due to the loss or impairment of valuable ecosystem services.

Laws Addressing Land Use Impacts on Wetlands

Wetlands are unique with respect to the local, state, and federal laws that govern their use. Federal laws that protect those wetlands designated as being "waters of the United States" include the provisions of Sections 404 and 401 of the Clean Water Act. Provisions of the 1985, 1990, 1995, and subsequent federal Farm Bills also address wetland protection. The Section 404 federal permit review process generally requires an endangered species consultation (USEPA 2012b).

In 1991 Wisconsin became the first state in the country to establish water quality standards for wetlands, under Chapter NR 103 of the Wisconsin Administrative Code, which allows the state to grant, deny, or condition federal wetland fill permits, essentially giving it veto authority over wetland filling activities. In addition, the Wisconsin DNR has authority over other actions that may affect wetlands under their jurisdiction. These include Wisconsin DNR planning, management, funding, and other regulatory decisions. This law led to significant decreases in authorized wetland filling, from 1,440 to less than 100 acres a year on average.

Numerous other wetland protections, mitigation requirements, fees, and other management requirements are enumerated in additional Wisconsin administrative rules and statutes, such as Chapter NR 115, Wis. Adm. Code, which provides statewide ***shoreland*** zoning standards for wetlands within the shoreland zone. Section 281.15 of the Wisconsin Statutes requires the Wisconsin DNR to protect the waters of the state, including wetlands. Section 281.36, Wis. Stats., gives the Wisconsin DNR the authority to regulate wetland filling activities in wetlands not protected under federal law; as a result, Wisconsin is one of only a few states in the nation that regulates wetland filling activities in all wetlands. Section 59.692, Wis. Stats., requires counties to adopt shoreland-wetland zoning ordinances to protect wetlands in unincorporated areas within 1,000 feet of lakes and flowages and within 300 feet of navigable streams. However, as of February 2012, the protection afforded wetlands has been reduced under new state legislation.

In setting permit conditions, these laws set policy and standards to protect, preserve, restore, and enhance the quality of wetlands in the state. The Wisconsin DNR must document functions and values of wetlands subject to regulatory decisions. However, the applicant for a permit must show that the activity affecting a wetland avoids and minimizes wetland impacts and that no practicable alternative to the wetland impact exists and no significant impacts will occur. The Wisconsin DNR makes the determination whether the standards are being met by the applicant.

Implementing wetland management laws requires that wetlands be identified and inventoried. To meet this need, the Wisconsin Wetland Inventory (WWI) (WDNR 2012b) was authorized by the legislature in 1978 as a means to obtain an accurate assessment of the status of wetlands in the state. Inventory maps (discussed earlier in the "Wisconsin Wetland Status" section) are used by state, federal, and local units of government to assist them in wetland regulation, planning, and protection programs. Maps are only an initial step in determining wetland status. The legal status of an area is determined in the field using standardized scientific methods (WDNR 2012d).

The U.S. Army Corps of Engineers, Wisconsin DNR, and local units of government have jurisdiction over discharges of fill into wetlands in the state. People who want to do anything that may negatively affect wetlands must first determine whether they need to obtain permits or approvals from one or more governmental units by contacting the nearest Wisconsin DNR field office.

Land Use and Changes in Wetland Function

Wetlands are typically interspersed among other community types, so activities on adjoining uplands can affect wetland characteristics and function. Residential, agricultural, and industrial development and road, dam, and utility construction often cause hydrologic changes and result in pollutants, sediments, and additional nutrients entering wetlands through surface water runoff. These changes in hydrology alter water chemistry and flow rates, which can affect animal life and lead to changes in vegetation. Vegetation changes can include increases in the abundance and extent of invasive plants, which often crowd out and can sometimes eliminate native species.

At a larger scale, when a watershed contains more than about 60% open land or younger forest (less than 15 years of age), snowmelt occurs more rapidly and can increase stream flow rates by up to three times. The rapid snowmelt can lead to flooding, channel erosion and sedimentation, and downstream transport of materials (Verry 1992). Also, in urban and agricultural areas, groundwater is sometimes withdrawn for residential, industrial, and irrigation uses to the point where water tables are lowered and wetlands are significantly impacted. The additional nutrients often supplied by these land uses can increase invasive wetland species, particularly reed canary grass and cat-tails (Mauer and Zedler 2002, Woo and Zedler 2002, Bernthal and Willis 2004).

While nonnative invasive species are significantly modifying some wetlands, statewide acreage inventories of these impacts are not available. Reed canary grass is considered an especially significant problem in shallow ditches and other wetlands where standing water is not always present. It is considered the most invasive species in the state by Invasive Plant Association of Wisconsin (IPAW) experts. Emergent Marsh communities in some parts of Wisconsin are being overtaken by the nonnative narrow-leaved cat-tail (*Typha angustifolia*) or hybrid cat-tail (*Typha* x *glauca*). Other invasive plants that are currently serious problems in Wisconsin wetlands are purple loosestrife, common reed, common buckthorn, and glossy buckthorn. Information on the management and control of these nonnative species can be found on the Wisconsin DNR and NatureServe websites.

During the Cutover of the late 19th and early 20th centuries, log slides, log drives, and related activities damaged streambanks and their associated riparian areas by gouging banks, raising and widening streambeds, smothering gravel substrates with sediments, and in some cases creating steep gullies and ***flashy*** flows that altered hydrology and destroyed some wetland habitats. Some riparian wetlands are still affected by these changes in ***stream morphology*** a century later (L. Kitchel, Wisconsin DNR, personal communication; M. Miller, Wisconsin DNR, personal communication).

Some streambed restoration projects have been undertaken on wetland-bounded streams that have been damaged by log drives and erosion unleashed by historical deforestation. These include stretches of the upper Wolf River (Forest Transition Ecological Landscape) and streams of the Western Coulees and Ridges and Southwest Savanna ecological landscapes. While these projects may have helped to restore some former streambed characteristics, they are often prohibitively costly (L. Kitchel, Wisconsin DNR, personal communication; M. Miller, Wisconsin DNR, personal communication).

Economic and Social Values of Wetlands

Wetlands, through the ecological functions noted in the "Issues of Composition, Structure, and Function" section above, have economic value through the many ecosystem services they provide, such as mitigating floods, buffering shorelines, protecting water quality by trapping sediments and removing nutrients, maintaining habitat for native plants and animals, and providing sites for education, scientific research, aesthetic enjoyment, and recreation. New research continually demonstrates associations among wetlands, water quality, economically important fish and wildlife species, and the preservation of many common and rare plant and animal species. Land-use plans recommend various levels of wetland preservation to maintain these economically valuable ecological functions.

While there is legitimate disagreement regarding how, or even whether, to attempt to assign economic value to wetlands, many wetland advocates agree it is important to acknowledge that wetlands provide a wide range of significant economic benefits via functions related to flood control, outdoor recreation, and water supply. Considering the values of these functions, one such study by the Coastal Alliance estimated the value of Wisconsin's remaining wetlands to be about $32 billion dollars annually (WWA 2012).

Economic contributions of wetland products and services include the following:

- Wild rice beds can be productive sources of wildlife food as well as a culturally important subsistence food. Wild rice beds occur in a number of drainage lakes and along some streams, now mostly in northern Wisconsin (WDNR 2012a).
- Sphagnum and other mosses are harvested commercially in central Wisconsin wetlands for use by the floral industry for germinating, decorating, and shipping plants and are also used as worm bedding.
- Commercial cranberry production in Wisconsin provides an economic value of about $166 million (NASS 2012), with much of the state's 18,000 acres in cranberry

This Great Lakes coastal wetland on Lake Superior includes excellent examples of marsh, fen, sedge meadow, and forested bog. The parallel beach ridges support stands of pine, spruce, and fir. Northwestern Wisconsin has exceptional opportunities to protect large wetland sites with unique properties. Photo by Eric Epstein, Wisconsin DNR.

*The vast coastal wetlands near the mouths of the Bad and Kakagon rivers have been protected by the Bad River Band of Lake Superior Ojibwa. Important wetland plants pictured here include wild rice (*Zizania *spp.), pickerel weed (*Pontederia cordata*), and sedges. Ashland County. Photo by Eric Epstein, Wisconsin DNR.*

*The floodplain of the lower Wolf River contains extensive, relatively undisturbed stands of lowland hardwood forest, shrub swamp, sedge meadow, and marsh. **Oxbow lakes**, backwater ponds, and **cut-off sloughs** are key parts of big river ecosystems in southern Wisconsin. Waupaca County near Fremont. Photo by Eric Epstein, Wisconsin DNR.*

production occurring in wetlands. However, an unquantified amount of permit-exempt impacts to wetlands also occur to partially offset this value.

- Other consumptive uses of wetlands, such as muck farming or other agricultural activities, can alter and/or degrade wetland integrity and water quality (Hanson and Bender 2007).
- Wetlands are also important for fulfilling personal and social needs, including recreation, aesthetics, research, and education. They provide open spaces, which are becoming increasingly rare as development in many landscapes intensifies and spreads. Hunters and anglers use them directly and indirectly for recreational pursuits. They can be used seasonally for canoeing, hiking, cross-country skiing, and gathering wild foods. Viewing and listening to wildlife are also popular wetland activities. Birds in wetlands are often particularly easy to observe, making wetlands favorite bird watching and photography areas. These aesthetic and recreational uses of wetlands provide substantial economic returns. For example, the total economic activity generated by hunting, fishing, and wildlife viewing in Wisconsin is approximately $3.7 billion (USFWS 2008). Many species of fish, waterfowl, aquatic mammals, herptiles, and songbirds rely heavily on wetlands. An unknown but sizable portion of this outdoor economic activity is attributable to wetlands.

Statewide Ecological Opportunities for Wetland Communities

In addition to protecting wetlands through regulations, the Wisconsin DNR and the U.S. Fish and Wildlife Service have acquired wetlands for wildlife and fisheries management, natural areas, and other public purposes in the state. These agencies, along with private nongovernmental conservation organizations (NGOs), have acquired hundreds of thousands of acres of wetlands and have partially restored many thousands of acres of drained wetlands. Tribal protection and management of wetlands, such as the Bad River-Kakagon Sloughs (Ashland County) and the Bayfield Peninsula's Raspberry Bay, are important due to the exceptional condition of these culturally significant examples, the protection and restoration of wild rice beds and their habitat, and active control of exotic plant species. Notable wetland acquisition, protection, management, planning, and restoration projects include the following:

- St. Louis River Estuary, including the St. Louis River National Estuarine Research Reserve (Douglas County)
- Apostle Islands-Bayfield Peninsula Coastal Wetlands (Bayfield and Ashland counties)
- Bibon Swamp (Bayfield County)
- Glacial Lake Grantsburg wildlife management complex in Burnett County (including Crex Meadows, Fish Lake, Amsterdam Sloughs, and Danbury State Wildlife Areas). Several state natural areas, Governor Knowles State Forest, and the St. Croix National Scenic Riverway are in the immediate vicinity, all of which contain or adjoin important wetland and aquatic resources.
- Numerous sites within the Chequamegon-Nicolet National Forest (Ashland, Bayfield, Florence, Forest, Langlade, Oconto, Oneida, Price, Sawyer, Taylor, and Vilas counties)
- Door Peninsula coastal wetlands including The Ridges Sanctuary, Mink River Estuary, North Bay, Shivering Sands, Toft Point (Door County)
- Green Bay West Shores Wildlife Area (Brown, Oconto, Marinette counties)
- Mead Wildlife Area (Marathon, Portage, Wood counties)
- Necedah National Wildlife Refuge; Meadow Valley, Sandhill, and Wood County Wildlife Areas; and the Black River State Forest (Jackson county)
- Upper Mississippi National Wildlife and Fish Refuge (Buffalo, Trempealeau, La Crosse, Vernon, Crawford, and Grant counties)
- Trempealeau National Wildlife Refuge (Trempealeau County)
- Lower Chippewa River (Tiffany and Dunnville Bottoms State Wildlife Areas, Nine Mile Island, Caryville Savanna and Nelson Trevino Bottoms State Natural Areas (Buffalo and Pepin counties)
- Lower Wolf River wetlands (Winnebago, Outagamie, Waupaca, and Shawano counties)
- Lower Black River (Van Loon State Wildlife Area, adjacent federal lands) (La Crosse and Trempealeau counties)

For over 10 miles, the upper portion of the Bois Brule River is bordered by alders and a conifer swamp mostly dominated by northern white-cedar. Numerous springs and seepages feed this stretch of the Bois Brule, which, despite its low gradient, is a coldwater stream. Brule River State Forest, Douglas County. Photo by Eric Epstein, Wisconsin DNR.

- Horicon Marsh (Dodge and Fond du Lac counties, includes Horicon National Wildlife Refuge and Horicon Marsh State Wildlife Area)
- Lake Koshkonong wetlands (Jefferson County)
- Lulu Lake-Mukwonago River watershed project (Walworth and Waukesha counties)
- Scuppernong River Basin (Waukesha and Jefferson counties)
- Lower Wisconsin River (Lower Wisconsin State Riverway, includes state parks, state wildlife areas, and state natural areas, extends from the Prairie du Sac dam west of Madison all the way to the Mississippi River) (Sauk, Dane, Richland, Iowa, Crawford and Grant counties)

Procedures for identifying potentially restorable wetlands in a basin and for assigning restoration priorities were identified in the Milwaukee River Basin Wetland Assessment Project report (Kline et al. 2006). The report describes the following tools that can be used for these purposes:

- A set of wetland-related "watershed metrics" that characterize ecological conditions in the watersheds and subwatersheds of the basin
- A Wildlife Habitat Decision Support Tool that planners can use to evaluate wildlife benefits provided by existing wetland habitats and a means of evaluating future land use scenarios. For instance, a planner could use this tool to help evaluate where wetland restoration can generate the most benefit for wildlife.
- A Water Quality Decision Support Tool that planners can use to evaluate the relative contributions of existing

Wet-mesic forests dominated by white pine and red maple are limited to a small number of sites in central Wisconsin, most of them in or on the periphery of extinct Glacial Lake Wisconsin. Rare plants and animals inhabit this community. Ketchum Creek Headwaters State Natural Area, Black River State Forest, Jackson County. Photo by Eric Epstein, Wisconsin DNR.

Wet and Wet-mesic prairies are now extremely rare in Wisconsin. Though virtually all remnants are small and many of them are isolated, they support a wealth of native plants and animals, some of which would no longer exist in Wisconsin without protection and proper management of these habitats. Allen Creek, Jefferson County. Photo by Eric Epstein, Wisconsin DNR.

This ditch has been filled as a major part of an effort to restore stream meanders and hydrological function to wet prairie, sedge meadow, marsh, and fen habitats within the upper Scuppernong River Basin. Kettle Moraine State Forest – Southern Unit, Waukesha County. Photo by Eric Epstein, Wisconsin DNR.

wetlands to downstream water quality in different watersheds. This can also be used to evaluate future land use scenarios and where wetland restoration can generate the most benefit for improving water quality.

- A Floodwater Storage Decision Support Tool
- Discussion of the uses and limitations of the project data and tools

The Milwaukee River Basin Wetland Assessment Project report also noted that decision managers should consider the following guidelines when setting priorities for wetland protection and restoration:

- Use objective scientific criteria to support protection and restoration decisions.

Interdunal wetlands are dynamic natural features dependent on functional dune systems and the longshore transport of sediments for their existence. They are very rare in Wisconsin, occurring in only a few locations. Apostle Islands National Lakeshore, Ashland County. Photo by Eric Epstein, Wisconsin DNR.

In addition to type rarity, the size, context, and composition of wetland communities can be highly significant. This floristically diverse Shore Fen at the mouth of the Raspberry River is part of a complex mosaic of wetland communities, forested uplands, and aquatic features. The site is protected by the Red Cliff Band of Lake Superior Ojibwa. Bayfield County. Photo by William E. Tans.

- Base wetland protection on existing wetland functions and values and their threats.
- Base wetland restoration on past wetland loss and the probability that a restoration will meet specific restoration goals or address environmental concerns.

Statewide, there are opportunities for identifying and protecting wetland communities, including (but not limited to) rare types such as Calcareous Fen, Boreal Rich Fen, Shore Fen, Interdunal Wetland, Coastal Plain Marsh, and Wet-mesic Prairie through the State Natural Areas program. Some NGOs within Wisconsin (e.g., Wisconsin Wetlands Association, The Nature Conservancy, St. Louis River Citizens Action Committee, Friends of the Mukwonago River, and other local land trusts) seek opportunities to protect rare and representative wetlands that are especially important in the areas in which they work. The individual ecological landscape chapters in this publication identify the ecological landscapes in which these and other features are especially well represented and offer the best opportunities for protection, restoration, and management. In addition, there are opportunities to improve the functional values of degraded wetlands by restoring disrupted hydrology and attempting to control invasive species. Adding culverts, rerouting roads and railroad beds out of wetlands, filling ditches, removing subsurface drainage tiles, and modifying groundwater withdrawal permits are examples of ways of partially restoring hydrologic function.

The best opportunities for preservation, enhancement, and restoration of wetland communities can be found in Table 2.3, which indicates those ecological landscapes that have occurrences of specific wetland communities and where they are relatively most abundant. The table can be used to identify those parts of the state with the best opportunities for protection, restoration, or acquisition of the various wetland types. When a highly ranked (i.e., rare) wetland type is present in only one or a few ecological landscapes and scarce in others (e.g., the Shore Fen or Interdunal Wetland communities), opportunities for protection become a higher priority in those respective ecological landscapes. In ecological landscapes with abundant wetland occurrences, opportunities may exist for protecting or restoring larger patches of more common or widespread wetland communities (e.g., Emergent Marsh or Floodplain Forest) that benefit certain assemblages of wildlife and plant species.

Wetland communities inventoried by Wisconsin DNR's Natural Heritage Inventory staff biologists are documented and ranked according to standardized and accepted assessment methodology. This information is then entered into a natural community database from which it can be retrieved and used for many purposes, including the selection of conservation projects. Basic ranking factors include wetland community condition (the degree of past disturbance and how that has affected present condition), size, and ecological context (how land cover and land use around the wetland affect it).

Table 2.3. *Wetland occurrences in Wisconsin's ecological landscapes. Red "XX" in body of table indicates a major opportunity; "X" indicates an important opportunity; "P" indicates the presence of that wetland community in the ecological landscape, and a blank indicates the wetland community is absent.*

WETLAND COMMUNITY	Central Lake Michigan Coastal	Central Sand Hills	Central Sand Plains	Forest Transition	North Central Forest	Northeast Sands	Northern Highland	Northern Lake Michigan Coastal	Northwest Lowlands	Northwest Sands	Southeast Glacial Plains	Southern Lake Michigan Coastal	Southwest Savanna	Superior Coastal Plain	Western Coulees and Ridges	Western Prairie
Alder Thicket (S4)	P	X	XX	X	XX	X	X	P	X	X	P			X	X	P
Bog Relict (S3)	P	X									XX	X			P	
Boreal Rich Fen (S2)					X	X	X	XX								
Calcareous Fen (S3)		XX	P								XX	X			P	
Coastal Plain Marsh (S1)		XX	X													
Emergent Marsh – Wild Rice (S3)	P	P	P	P	X	P	XX	P		XX	X			XX	X	P
Emergent Marsh (S4)	X	XX	X	X	XX	X	XX	XX	X	XX	XX	X	P	XX	XX	XX
Ephemeral Pond (SU)	X	P		X	XX	P	X	X	P	P	X	X	P	P	X	P
Floodplain Forest (S3)	X	X	XX	X	X	P	P	X		P	XX	P	P	X	XX	X
Great Lakes Alkaline Rockshore (S2)								XX								
Great Lakes Ridge and Swale (S2)	XX							XX						P		
Interdunal Wetland (S1)	X							X						XX		
Northern Hardwood Swamp (S3)	X	X	X	X	XX	X	X	X	P	X	X			X	P	
Northern Sedge Meadow (S3)	X	X	XX	X	XX	X	XX	XX	XX	XX	X			X	X	P
Northern Wet Forest (S4)	X	XX	XX	XX	XX	X	XX	X	XX	XX	X			X	X	P
Northern Wet-mesic Forest (S3S4)	X	P		XX	XX	XX	X	XX	X	X	X	P		X	P	
Open Bog (S4)	P	X	XX	X	XX	X	XX	P	XX	XX				XX		
Shore Fen (S2)								X						XX		
Shrub Carr (S4)	X	XX	XX	X	X	P	X	XX	P	P	XX	X	P	X	XX	P
Southern Hardwood Swamp (S2)	P										X	X			P	
Southern Sedge Meadow (S3)	X	XX	X	P				X			XX	X	P		X	P
Southern Tamarack Swamp (rich) (S3)		X	X								XX	X			X	
Wet Prairie (SU)		X	P								X	X	P		X	P
Wet-mesic Prairie (S2)		XX	P								XX	XX	X		X	
White Pine - Red Maple Swamp (S2)			XX												X	

See table notes on next page.

Once a draft list of sites with restoration or management potential is developed, a closer look at site characteristics and settings is needed. For example, the Wisconsin Wetland Inventory maps and the wetland communities documented in Wisconsin DNR's Natural Heritage Inventory statewide database could be, and often have been, used as starting points for selecting and initiating restoration, management, and protection efforts. An evaluation of inventory gaps would specify additional needed work. The Wisconsin Wetlands Association and the Wisconsin DNR have produced the *Wetland Restoration Handbook for Wisconsin Landowners* (Thompson and Luthin 2010), which, while aimed at private landowner projects, can be used to evaluate the restoration potential of just about any wetland site.

Wetland assessments and other information used when seeking wetland management and protection opportunities must be interpreted somewhat cautiously. Information may become quickly outdated, and inventories for certain ecological landscapes and associated wetland communities may be incomplete or altogether lacking. Data obtained from varied sources may not be in compatible formats, scales, or precision (degrees of spatial accuracy).

Economic and social issues often constrain management options in wetlands. For example, when food commodity prices are high and conservation incentives are comparatively low or nonexistent, farmers may be inclined to use previously drained wetlands for crop production rather than for wetland restoration. Wetlands altered for production of crops, such as cranberries or cultivated "wild" ("paddy") rice, may not become part of larger wetland restoration areas surrounding them. Wetland values may be overlooked or poorly understood by decision makers and therefore undervalued when making decisions based on just economic criteria.

Table 2.3 notes.

Definitions:

Major Opportunity – Type extensively represented by multiple significant occurrences, or ecological landscape is appropriate for major restoration activities.
Important Opportunity – Type not extensive or common in ecological landscape but represented by one to several significant occurrences, or type restricted to one or few ecological landscapes.
Present – Better opportunities exist on other ecological landscape, or opportunities not adequately evaluated.
Absent – Type absent, or no occurrences documented.

State Rank:

S1 = Critically imperiled in Wisconsin because of extreme rarity (5 or fewer ***element occurrences*** or very few remaining individuals or acres) or some factor(s) making it vulnerable to extirpation.
S2 = Imperiled in Wisconsin because of rarity (6 to 20 element occurrences or few remaining individuals or acres) or some factor(s) making it very vulnerable to extirpation from the state.
S3 = Rare or uncommon in Wisconsin (21 to 100 element occurrences).
S4 = Apparently secure in Wisconsin, with many element occurrences.
S5 = Demonstrably secure in Wisconsin and essentially ineradicable under present conditions.
SU = Possibly in peril in the state, but status is uncertain. More information is needed.
NR = Not ranked.

Ecological Opportunities by Ecological Landscape

There are opportunities for preserving and managing wetlands throughout the state and in all ecological landscapes. For details, see "Statewide Ecological Opportunities for Wetland Communities" above and the "Management Opportunities for Important Ecological Features" section in the individual ecological landscape chapters (Chapters 8-23). It may also be helpful to review the "Summary of Ecological Features and Management Opportunities at the Ecological Landscape Scale" section in Chapter 6 and the table in Appendix E, "Opportunities for Sustaining Natural Communities in Each Ecological Landscape," in Part 3 of the book, "Supporting Materials." In addition, opportunities for "open wetland" communities are found in the "Grassland Communities" section, and opportunities for "forested wetland" communities are found in the "Southern Forest Communities" and "Northern Forest Communities" sections of this chapter.

New Findings, Opportunities, and Conservation Needs

Wetland science continues to evolve, and data gathering provides new information pertaining to the status and management needs of Wisconsin's wetlands. Some recent information and activities that may help address the opportunities and challenges in protecting and managing functional wetlands are as follows:

- The Wisconsin Wetlands Association has compiled a list of one hundred wetlands in its Wetland Gems project. These wetlands were selected as among the best in the state. This list was compiled using information from State Natural Area, Wisconsin's Land Legacy, Wisconsin Wildlife Action Plan, The Nature Conservancy, Coastal Wetlands, and Important Bird Area data sets.
- The Wisconsin Wildlife Action Plan lists numerous examples of high quality wetlands of various types in each ecological landscape in the state. Many of these are in areas where there are additional opportunities to restore or protect more wetland acreage through cooperative management of adjacent lands or expansion of existing Wisconsin DNR or other agency project boundaries.
- The Lake Superior National Estuarine Research Reserve (NERR) on the St. Louis River Estuary in Douglas County was established in 2010 by the National Oceanic and

Atmospheric Administration, University of Wisconsin-Extension, Wisconsin DNR, and many partners. The Lake Superior NERR is a national research and education effort focused on improving water quality, aquatic, wetland, and coastal habitats, and quality of life for people in the Great Lakes region (UWEX 2012).

- Extensive wetland acquisition by The Nature Conservancy (TNC) has been accomplished recently at North Bay along Lake Michigan in Door County. TNC and their many partners (e.g., public agencies, universities, and other NGOs, such as the Door County Land Trust) have other protection projects that include ecologically significant wetlands across Wisconsin.
- The Nature Conservancy, Friends of the Mukwonago River, Wisconsin DNR, and others continue to work to protect the irreplaceable resources of the Mukwonago River Watershed in rapidly developing southeastern Wisconsin.
- Recent state natural area designations have given additional protections to significant wetlands, such as Big Bay Bog in Big Bay State Park on Madeline Island, Ashland County. Recent DNR master plans have created a framework for evaluating, protecting, and managing large wetland areas such as those along the Brule River (Brule River State Forest, Douglas County), within the Northern Highland Ecological Landscape (Northern Highland-American Legion State Forest), and bordering the lower Wolf River (Lower Wolf River Bottoms Natural Resource Area in Shawano, Waupaca, Outagamie, and Winnebago counties).
- The U.S. Forest Service Chequamegon-Nicolet National Forest staff, after years of meeting with an interdisciplinary team of scientists representing forestry, wildlife, endangered resources, and recreation, has used various designations to offer appropriate protection to a variety of exceptionally valuable wetlands on U.S. Forest Service lands that provide numerous ecological and economic benefits to the citizens of Wisconsin and the United States (USFS 2004).
- Recent reintroductions of the Trumpeter Swan and Whooping Crane have shown that wetland protection is a critical component of maintaining viable populations of rare species, and those that are more common and widespread.
- Wetland inventory projects have been undertaken by various programs, including the Natural Heritage Inventory (e.g., recently at Green Bay West Shores State Wildlife Area and along the Lake Superior coast), to type and classify wetlands, describe and assess the condition of wetland communities, document values to fish and wildlife (including rare species), and identify land use and land cover changes and trends.
- The first National Wetland Condition Assessment survey began in 2011, implemented by the Environmental Protection Agency and its state, federal, and tribal partners (USEPA 2012a).
- The Wisconsin Wetlands Association is working (as of mid-2010) to complete a Wisconsin Wetlands Threats Analysis (WWA 2011). This analysis will help wetland managers and conservation planners assess and plan wetland protection and management needs and priorities across the state.
- Impacts of groundwater withdrawals from high capacity wells for irrigation and municipal and industrial wells in southeastern, northeastern, and south central Wisconsin include shrinkage of wetlands due to loss of recharge water (Hunt et al. 2001).
- Wetland integrity may be adversely impacted by developments that include or result in disruptive hydrologic modifications, increased discharge of polluted storm water, the introduction of invasive species, and stand isolation.
- Increased degradation and other impacts to wetlands are expected from expanding residential, commercial, and industrial areas; more impervious surfaces; and farm operations. Runoff entering wetlands from these types of development is often laden with sediment and pollutants and in summer may be warmed greatly by heated pavement. In some cases, the water in wetlands receiving runoff from heated pavement can be become so warm that some species perish from a lack of oxygen or move away to seek cooler water.
- New trails and roads may impact adjacent or nearby wetlands, especially with the proliferation of ATV ownership and use (IASA 2006), the conversion of snowmobile trails to ATV trails, and the construction of new ATV trails. Erosion of trails can create muddy holes, which riders may avoid by detouring through wetlands or creating new pathways through erodible soils adjacent to wetlands. Trails in steep terrain characteristic of the Driftless Area are highly erodible and easily damaged, especially where there is groundwater seepage, and require especially careful routing.

Scientific names of species mentioned in the wetland communities assessment.

Common name	Scientific name
Alders	*Alnus* spp.
Black spruce	*Picea mariana*
Box elder	*Acer negundo*
Canada blue-joint grass	*Calamagrostis canadensis*
Canvasback	*Aythya valisineria*
Common buckthorn	*Rhamnus cathartica*
Common carp	*Cyprinus carpio*
Common reed	*Phragmites australis*
Dogwoods	*Cornus* spp.
Dwarf lake iris	*Iris lacustris*
Eastern massasauga rattlesnake	*Sistrurus catenatus*
Glossy buckthorn	*Rhamnus frangula*
Hine's emerald dragonfly	*Somatochlora hineana*
Hybrid cat-tail	*Typha* x *glauca*
Narrow-leaved cat-tail	*Typha angustifolia*
Northern white-cedar	*Thuja occidentalis*
Pickerel weed	*Pontederia cordata*
Prothonotary Warbler[a]	*Protonotaria citrea*
Purple loosestrife	*Lythrum salicaria*
Red maple	*Acer rubrum*
Red-shouldered Hawk	*Buteo lineatus*
Reed canary grass	*Phalaris arundinacea*
Sedges	*Carex* spp.
Sphagnum mosses	*Sphagnum* spp.
Swamp metalmark	*Calephelis muticum*
Tamarack	*Larix laricina*
Trumpeter Swan	*Cygnus buccinator*
Tundra Swan	*Cygnus columbianus*
Tussock sedge	*Carex stricta*
Viburnums	*Viburnum* spp.
White pine	*Pinus strobus*
Whooping Crane	*Grus americana*
Wild rice	*Zizania* spp.
Willows	Salix spp.
Wilson's Phalarope	*Phalaropus tricolor*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologist Union.

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Aquatic Communities

Community Description

Wisconsin's aquatic resources are diverse and abundant, ranging from small ephemeral ponds to the largest freshwater lake by surface area in the world. The Mississippi, North America's largest river, forms much of the state's western boundary. Wisconsin is also noted for its plentiful supply of groundwater, much of which emerges to replenish surface waters. Our surface and ground waters support many species, communities, ecological processes, and human uses and needs.

In most of the state, Wisconsin's aquatic communities were shaped by the last glacial advance, which covered the state with ice from about 25,000 years ago until about 10,000–12,000 years ago. Fine-textured glacial deposits, including some tills and lacustrine materials, are only slowly permeable to water, and the depth and configuration of these deposits often controls the level of water tables. Landforms created by glacial processes also influenced the development of aquatic features. Stranded ice blocks that slowly melted left kettles that often contain lakes and wetlands, and morainal hills and ridges influence the paths of rivers and streams.

The weight of glacial ice depressed the earth's crust, which slowly rebounded after the glacier melted. This postglacial rebound resulted in the opening and closing of connections between drainages, which modified and reformed some of the drainages and basins, leaving the current aquatic landscape. Differential isostatic rebound is still occurring today with the eastern end of Lake Superior rising faster than the western end, drowning the mouths of rivers on the western end of Lake Superior. Erosion and sedimentation continue to influence the current physical aquatic landscape.

The last glacier did not cover southwestern Wisconsin's Driftless Area, and that region shows characteristics of unglaciated terrain, such as a classic branching (dendritic) stream pattern, few natural lakes, and steeper, more eroded terrain with frequent bedrock outcrops. The rest of the state, which was covered by glaciers, generally has less topographic relief and sinuous rivers with less average elevation drop. The glaciers also left numerous natural lakes and spring ponds, especially in the north and southeast. The Northern Highland Ecological Landscape in north central Wisconsin hosts one of the largest concentrations of glacial lakes in North America. Wisconsin is bordered by two Great Lakes: Superior on the north and Michigan on the east. The Mississippi and St. Croix rivers form most of Wisconsin's western border. Hydrologically, the state is divided into three major basins: the Lake Superior, Lake Michigan, and Mississippi River basins. Based on hydrological boundaries, these three major basins are further divided into 24 discrete hydrologic basins that generally conform to the boundaries of the drainage basins of the state's major streams (see the "Water Basins" map in Appendix G, "Statewide Maps," in Part 3 of the book).

These 24 basins are further divided into 330 watersheds, which are the basic geographic units for Wisconsin DNR's water management programs. These watersheds support approximately 12,600 perennial rivers and streams comprising about 37,308 river and stream miles (WDNR 2015e). (For the purpose of this publication, stream miles do not include the lake or impoundment portion of any stream.) Approximately 47,800 miles of intermittent streams combine for a total of 85,000 miles of waterways. There are more than 15,000 inland lakes, varying widely in size, hydrology, and limnological characteristics. In addition, 3,800 dams remain that form impoundments and flowages on state waterways.

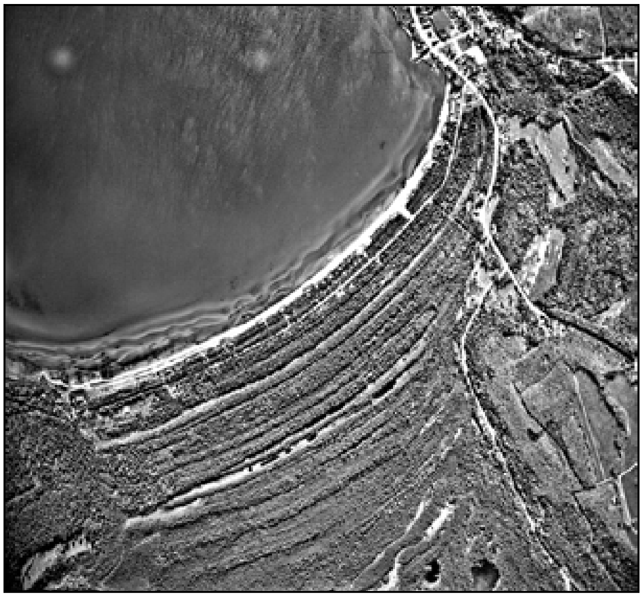
Wisconsin's aquatic resources have been impacted and modified to varying degrees by human activities since the area was populated by Euro-Americans. Major changes began during a period of rapid agricultural development in southern Wisconsin during the 1830s and heavy logging in northern Wisconsin during the late 1800s and early 1900s (WHS 2012). While the need to conserve soil and protect water quality was recognized by some, water resource degradation continued with the industrialization of the 1920s to the 1960s and has continued into the current era of residential and recreational development.

Great Lakes

Wisconsin's Great Lakes shorelines for Lakes Superior and Michigan total approximately 1,000 miles. The Great Lakes shorelines also support Wisconsin's highest human population density and the majority of its industrial base, especially along Lake Michigan and Green Bay. State waters include 1.7 million acres of Lake Superior and 4.7 million acres of Lake Michigan, including Green Bay. These two Great Lakes are considered and managed as interstate and international waters. Nearly a third (11 million acres) of Wisconsin's 35 million acres and a third of its river miles drain to these two Great Lakes.

■ **Lake Michigan.** Lake Michigan, the second largest of the Great Lakes by surface area, covers 22,300 square miles shared by Michigan, Indiana, Illinois, Wisconsin, and the province of Ontario, Canada. Lake Michigan is a complex aquatic resource of national significance, supplying drinking water for over 10 million people, providing critical economic resources, a small amount of commercial fishing, and many recreational opportunities (WDNR 2012c). Unique landforms, natural communities, and species assemblages are associated with its shorelines, and these are dependent on natural processes for their maintenance. For more information, see the chapters on the Northern Lake Michigan Coastal, Central Lake Michigan Coastal, and Southern Lake Michigan Coastal ecological landscapes.

■ **Lake Superior.** Lake Superior, the largest freshwater lake in the world by surface area, covers 31,700 square miles. It is the cleanest and healthiest of the Great Lakes, with lower levels



Complex ridge-and-swale landforms reflect former Lake Michigan water levels. Unusual plant communities and numerous rare species (some of them endemic to the Great Lakes shores) are associated with such features. The Ridges Sanctuary, Door County. Photo Wisconsin DNR staff.

of development, urbanization, and industrialization along its shores and less pollution affecting its waters compared with the other Great Lakes (WDNR 2012d). Bordering Ontario, Michigan, Wisconsin, and Minnesota, Lake Superior is an international resource, popular for boating, sport angling, and commercial fishing. Wisconsin's Lake Superior shoreline is especially notable for its concentration of freshwater estuaries and ***sandscapes***. See Chapter 21, "Superior Coastal Plain Ecological Landscape," for additional information.

Inland Lakes and Ponds

Inland lakes and ponds are naturally occurring bodies of standing water with a huge diversity in size, depth, configuration, water chemistry, and biota. Their surface area can range from less than one acre (typically referred to as "ponds") to enormous waterbodies, such as Lake Winnebago (Winnebago County), the state's largest inland lake at 137,708 acres (WDNR 2009c). Depth can range from less than one foot to 236-foot-deep Green Lake (Wisconsin's deepest inland lake, in Green Lake County). Glaciation, postglacial water flow, soil characteristics, topography, bedrock and glacial deposit composition, land cover, land use, and other factors can all combine to determine the physical and chemical characteristics of any given lake. The relatively dense concentration of glacial kettle lakes within the Northern Highland Ecological Landscape is globally important. Some of the lake types there are rare and support many rare aquatic and wetland organisms.

Inland lakes and ponds cover almost one million acres, nearly 3% of the state's area, and vary greatly in size, shape, depth, and type (WDNR 2009c). Many of Wisconsin's inland

*Freshwater estuaries are important features of the southwestern Lake Superior coast. The diverse wetlands associated with these **drowned river mouths** provide habitat for many rare plants and animals. Photo by Eric Epstein, Wisconsin DNR.*

This deep, softwater seepage lake occurs in Vilas County in the Northern Highland Ecological Landscape. The undeveloped lake is bordered by old-growth hemlock-hardwood forest and conifer swamps. Photo by Eric Epstein, Wisconsin DNR.

Aurora Lake is an undeveloped, shallow, softwater drainage lake that supports extensive beds of aquatic macrophytes. Aurora Lake State Natural Area, Northern Highland-American Legion State Forest, Vilas County. Photo by Thomas Meyer, Wisconsin DNR.

lakes are in the north central, northwestern, and northeastern parts of the state, especially in the Northern Highland, North Central Forest, and Northwest Sands ecological landscapes, but also in the western and eastern lobes of the Forest Transition Ecological Landscape. Numerous lakes, including some that are very large, occur in southeastern Wisconsin in the Southeast Glacial Plains Ecological Landscape. A large portion of the larger lakes in the Southeast Glacial Plains are supplied by inflowing rivers and streams (drainage lakes). Areas of seepage (groundwater-fed) lakes that support unique aquatic plant communities occur in the Central Sand Hills Ecological Landscape. More than 90% of the state's total lake surface area is in the 3,620 lakes that are larger than 20 acres. About 13% of Wisconsin's lakes are artificial, created by impounding streams and rivers or by excavation.

Lakes are classified using biological, physical, chemical, and hydrological data to guide lake and watershed management and protect water quality. There are a number of classification systems for aquatic resources, depending on the goals of management. Two of the primary systems for classifying lakes are based on "lake natural community" and "shoreland development" classification systems.

Lake natural community classifications are used by the Wisconsin DNR for water quality monitoring and biological management. Under this system, lakes are classified primarily by the following:

- lake size
- thermal ***stratification*** characteristics (mixed or stratified)
- hydrology (i.e., drainage lakes with both an inflow and outflow, seepage lakes with no inlet or outlet, spring lakes with an outlet but no inlet and fed by groundwater, and drained lakes with an outlet but no inlet without groundwater input) (Figure 2.22).
- watershed size (if the watershed is less than four square miles in size, the lake is classified as a headwater drainage lake; if the watershed is greater than or equal to four square miles, the lake is classified as a lowland drainage lake; Emmons et al. 1999).

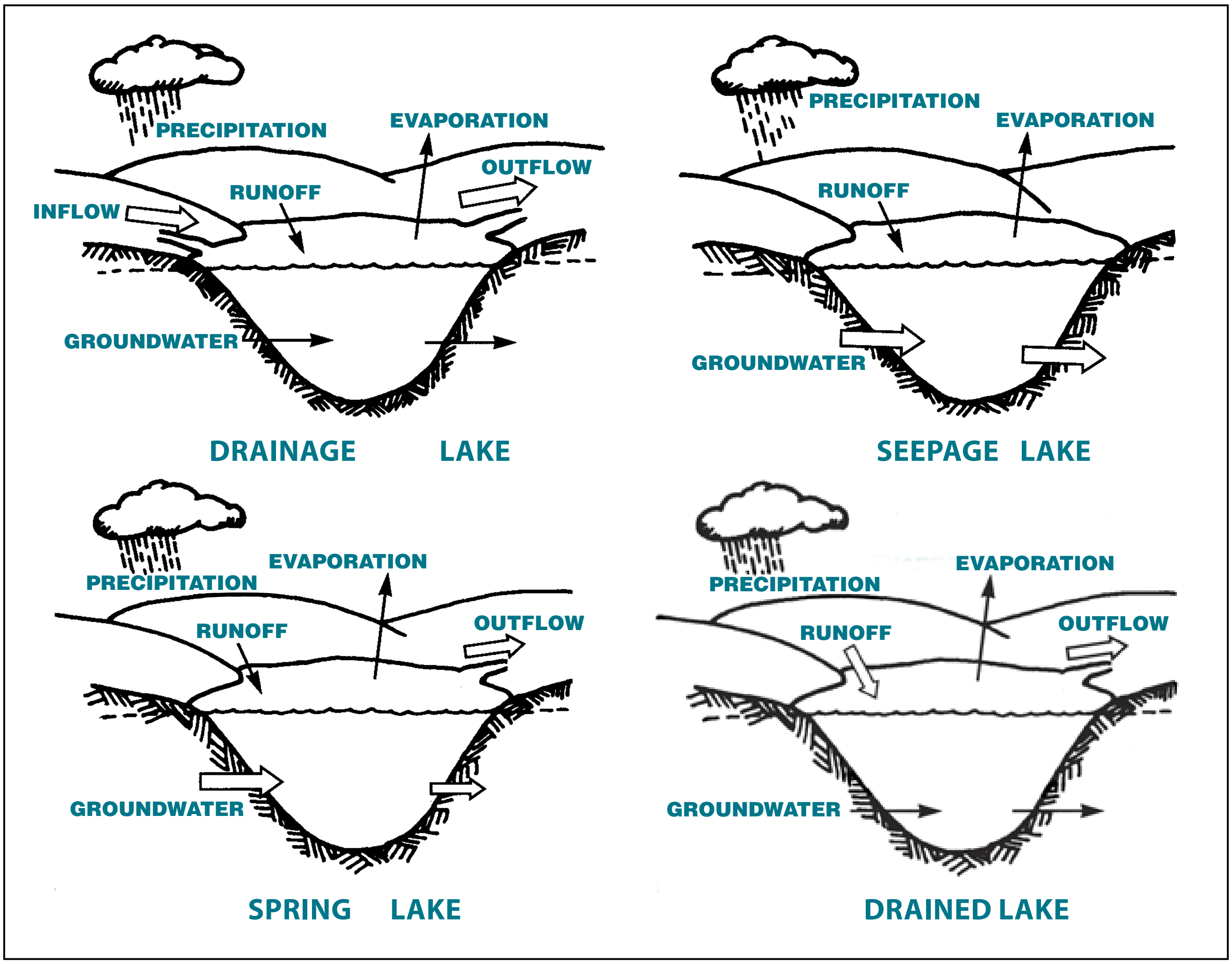


Figure 2.22. *Hydrology of lakes found in Wisconsin (Shaw et al. 2000). Figure courtesy of the Board of Regents of the University of Wisconsin.*

Most lakes fall into one of the ten "lake natural community" types shown in Table 2.4.

The shoreland development classification system is used by local zoning authorities in making land use decisions. This system is based on lake characteristics and how they will respond to various land use related stresses, such as nutrient pollution and overland storm water runoff. This approach to lake management allows the lake's current level of development and the ability to support additional growth. Three classes of lakes are commonly used (UWEX 1999):

- Natural environmental lakes/wild lakes (little or no shoreline development; protects natural beauty, wildlife diversity or rarity, and water purity; vulnerable to development and recreational use);
- Intermediate lakes (low density shoreline development; moderate recreational use; moderately sensitive to shoreland development; maintains relatively intact natural resources, ongoing development patterns are okay as long as water quality and habitat values are not degraded);
- General development lakes (moderate to high level of existing development or lakes are so heavily developed that changes to shoreland zoning are unlikely to affect resource values; more tolerant of shoreline development; focus on restoration rather than prevention of degradation).

Rivers and Streams

Wisconsin's 37,308 perennial river and stream miles reflect the state's regionally distinct hydrologic patterns, from the steep terrain and deeply incised dendritic streams of the unglaciated Driftless Area to the water-rich northern forests with numerous interconnected rivers, streams, lakes, and wetlands. ***Baseflow***-dominant coldwater streams occur

Shallow, softwater seepage lakes are common features in some of the sandy ecological landscapes of northern Wisconsin. This undeveloped lake has an upland shore and supports dense beds of floating-leaved and submergent aquatic vegetation. Use by invertebrates, amphibians, and waterbirds is heavy. Northwest Sands Ecological Landscape. Photo by Eric Epstein, Wisconsin DNR.

Headwaters of small trout stream in southern Wisconsin. Photo by Jeff Martin.

Table 2.4. *Lake natural community types.*

Lake natural community	Stratification status	Hydrology
Lakes < 10 acres – small	Variable[a]	Any
Lakes ≥10 acres		
Shallow seepage	Mixed	Seepage
Shallow headwater	Mixed	Headwater drainage
Shallow lowland	Mixed	Lowland drainage
Deep seepage	Stratified	Seepage
Deep headwater	Stratified	Headwater drainage
Deep lowland	Stratified	Lowland drainage
Other classification (any size)		
Spring ponds[b]	Variable	Spring hydrology
Two-story fishery lakes[c]	Stratified	Any
Impounded flowing waters[d]	Variable	Headwater or lowland drainage

Source: Table from Wisconsin 2012 Consolidated Assessment and Listing Methodology (WisCALM) (WDNR 2015h).
[a]May be either mixed of stratified, depending on a number of factors.
[b]Based also on historica;lly supporting a cold water fishery.
[c]Based also on historically supporting a native cold water fishery.
[d]Greater than a 14-day residence time under summertime low flow conditions.

in the state's western portion (Driftless Area) and far northeastern corner and are scattered in north central and northwestern Wisconsin (Figure 2.23). Coldwater streams are almost entirely missing from the central and eastern portions of the state, with the notable exception of the coldwater streams coming from the end moraine on the western edge of the Central Sand Hills Ecological Landscape.

Large rivers are defined (for ecological assessment purposes) as having at least 3 kilometers of contiguous river channel too deep (>1.5 meters) to be sampled effectively by wading. By this definition, Wisconsin has at least 40 large rivers with a combined length of over 2,400 miles—all of which are considered warmwater rivers. Wisconsin's largest and most diverse warmwater rivers are the

- Mississippi River
- Wisconsin River below Tomahawk
- St. Croix River below the mouth of the Clam River
- Chippewa River below the mouth of the Flambeau River
- Flambeau River below the confluence of the north and south forks
- Menominee River below the Highway 2/141 bridge
- Wolf River below Schiocton
- Red Cedar River below Menominee
- Black River in La Crosse County
- Fox River below the mouth of the Puchyan and between Lake Winnebago and Green Bay
- Rock River below Lake Koshkonong

Large warmwater rivers support diverse warmwater fish communities and some of the highest diversity and abundance of freshwater mussels in North America. In general, even when impacted by hydroelectric dams, a large river system with relatively few other ecologically damaging modifications will have a higher biological diversity than smaller flowing waters. In part, this reflects a greater diversity of habitats, including large woody debris, deep pools, riverine lakes, varied substrates, connectivity to wetlands such as lowland forests, shrub swamps, sedge meadows and marshes, and ecologically diverse tributaries.

Through Wisconsin's varied ecological landscapes flow a diverse web of coldwater creeks,

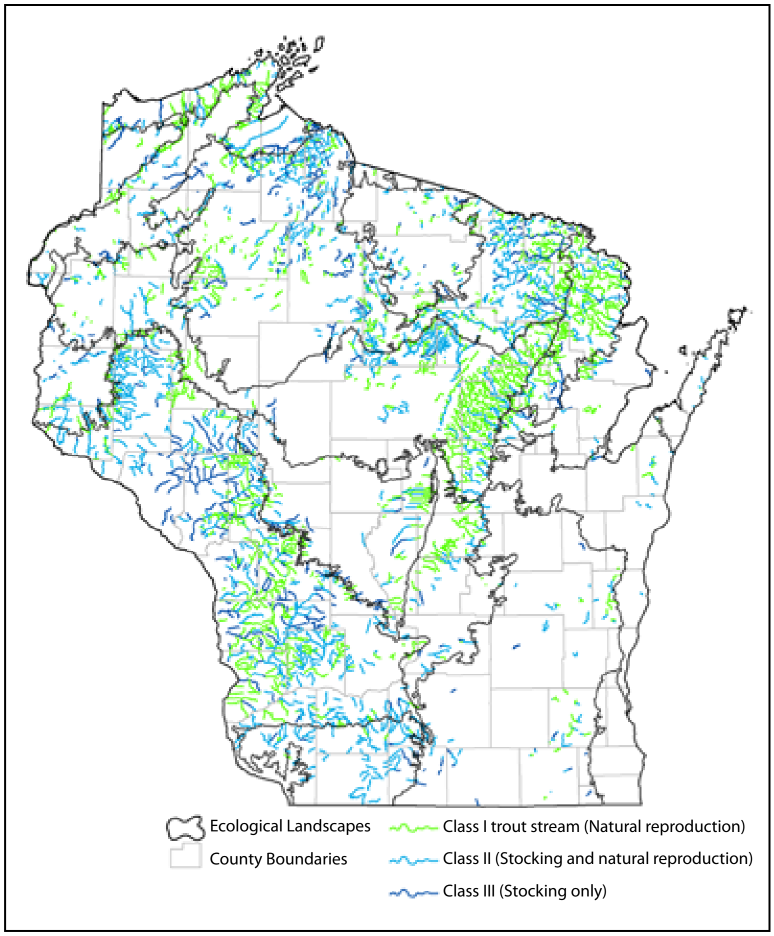


Figure 2.23. *Coldwater streams in Wisconsin that support trout and other coldwater communities.*

The lower Wolf River, several of its tributaries, and the Winnebago Pool lakes support globally important populations of the lake sturgeon. Photo by Eric Engbretson.

The absence of shoreline development, unpolluted water, and undisturbed substrate are some of the characteristics that promote native aquatic biodiversity in Wisconsin streams such as this. These conditions and native vegetation allow a diverse assemblage of aquatic invertebrates, fish, herptiles, birds, and mammals to thrive while also protecting recreational, scenic, and economic values. Photo by Eric Epstein, Wisconsin DNR.

Upper Namekagon River lined with alder in Bayfield County. Photo by Jeff Martin.

coolwater mainstem streams, and large warmwater rivers that support both a wealth of biological diversity and a host of recreational activities. A sampling of the most well-known coolwater and warmwater rivers includes the Bois Brule, St. Croix, Namekagon, and upper Chippewa rivers in northwest Wisconsin; the Wisconsin and Flambeau rivers in the north central part of the state; the Menominee, Pine, and Peshtigo rivers in the northeast; the Yellow, Black, and Tomorrow rivers across central Wisconsin; and the Mississippi, Black, lower Wisconsin, Kickapoo, and Mukwonago across the southern part of the state. In addition to providing habitat and recreation, Wisconsin's rivers offer scenic beauty, furnish electric energy, move sediments and nutrients, dilute municipal and industrial wastes, and supply water for drinking and industrial processes.

Grouping rivers and streams into classes based on similar aquatic (physical, chemical, biotic, hydrologic) characteristics enhances the ability to monitor and manage them for water

The floodplain of the lower Wolf River is broad and complex, supporting extensive stands of floodplain forest, shrub swamp, and emergent marsh. Colic Bayou, Waupaca County. Photo by Eric Epstein, Wisconsin DNR.

quality standards and fisheries. A classification system for Wisconsin's rivers and streams was developed using a U.S. Geological Survey/Wisconsin DNR Bureau of Science Services model based on observed and predicted flow and water temperatures. Wisconsin's 11 river and stream natural communities are classified as follows:

- Ephemeral: Channels with water flow only after precipitation events. No fish and few or no aquatic invertebrates are present.
- Macroinvertebrate: Very small, almost always intermittent, streams
- Cold headwater: Small perennial streams with cold summer temperatures
- Cold mainstem: Moderate to large but still wadeable perennial streams with cold summer temperatures
- Cool (cold-transition) headwater: Small, usually perennial streams with cold to cool summer temperatures
- Cool (cold-transition) mainstem: Moderate to large but still wadeable perennial streams with cold to cool summer temperatures
- Cool (warm-transition) headwater: Small, sometimes intermittent streams with cool to warm summer temperatures
- Cool (warm-transition) mainstem: Moderate to large but still wadeable perennial streams with cool to warm summer temperatures
- Warm headwater: Small, usually intermittent streams with warm summer temperatures
- Warm mainstem: Moderate to large still wadeable perennial streams with relatively warm summer temperatures
- Warm rivers: Non-wadeable large to very large rivers with warm summer temperatures

Springs

Springs are a critical natural resource, supplying water for lakes, streams, and wetlands. In addition to lending scenic beauty to Wisconsin's public and private lands, the habitats created or sustained by springs include wetlands such as sedge meadows and fens. These habitats harbor endangered and threatened species such as the Hine's emerald dragonfly (*Somatochlora hineana*), which is dependent on the flow of spring water for survival. Springs also provide the cool, oxygen-rich water necessary for trout survival. For researchers, springs also provide windows to the groundwater; springs are important points of groundwater discharge, sources for chemical analysis, and places to directly measure groundwater elevation. Springs are important ecological and cultural features no matter where they occur and merit strong protection. See the "Groundwater" section of this chapter for additional information on the vital interplay of groundwater and springs.

This undeveloped spring pond supports a coldwater community and, via its outlet stream, feeds the upper St. Croix River. Southern Douglas County. Photo by Eric Epstein, Wisconsin DNR.

Ephemeral Ponds

Ephemeral ponds are isolated depressions with impeded drainage that hold water for part of the growing season (e.g., following snowmelt and spring rains). They typically dry out by mid-summer. Ephemeral ponds (also referred to as vernal ponds or vernal pools) are included in the Wisconsin Natural Heritage Inventory classification with lakes rather than wetlands (WDNR 2009d). They are definable by their small scale, shallow depth, unique hydrology, isolation, and distinctive structure, composition, and function.

Ephemeral ponds are biologically productive during their relatively brief seasonal existence and provide critical breeding habitat for specialized invertebrates such as fairy shrimp (Wisconsin has at least three species, all in the family of crustaceans known as the Chirocephalidae) as well as for many amphibians such as the wood frog (*Rana sylvatica*) and several salamander species. Ephemeral ponds also provide feeding, resting, and/or breeding habitat for many birds and a source of food for herptiles and mammals. They contribute in many ways to support the biodiversity of the other habitats within which they are embedded (usually, but not always, forests) and to the larger landscape.

Common wetland plants found in this community include water-parsnip (*Sium suave*), yellow water crowfoot (*Ranunculus flabellaris*), orange jewelweed (*Impatiens capensis*), marsh mermaid-weed (*Proserpinaca palustris*), white grass (*Leersia virginica*), blue-joint grass (*Calamagrostis canadensis*), floating manna grass (*Glyceria septentrionalis*), fowl manna grass (*Glyceria striata*), spotted water-hemlock (*Cicuta maculata*), smartweeds (*Polygonum* spp.), and various sedges (especially *Carex* spp.). Ephemeral ponds also provide habitat for many rare species, including two Wisconsin Endangered plants—Hall's bulrush (*Schoeoplactus hallii*) and false hop sedge (*Carex lupuliformis*), the Wisconsin Threatened Blanding's turtle (*Emydoidea blandingii*), the Wisconsin Special Concern Solitary Sandpiper (*Tringa solitaria*), and others.

Ephemeral ponds typically hold water for several weeks to several months, especially in the spring following snowmelt and spring rains. These small features provide critical habitat for amphibians and specialized invertebrates and are also used by many other organisms. Penokee Range, northern Iron County. Photo by Eric Epstein, Wisconsin DNR.

Trees adjacent to ephemeral ponds provide a variety of benefits, such as maintaining cool water temperatures, adding structural complexity to the surrounding habitat, preventing premature drying, and providing materials for the food web. The annual input of leaves from trees around the ponds supports a detritus-based food web and a variety of macroinvertebrates and microorganisms that are part of that food web.

Key management considerations for ephemeral ponds include the protection of site hydrology; maintaining important structural features such as living trees, dead trees, and thickets of shrubs or saplings; and avoiding the isolation of ponds from surroundings habitats (such as forests) from the construction of roads or other infrastructure.

For details on the ephemeral pond community types, see Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin."

Groundwater

Groundwater functions as a critical source of fresh water to a major portion of the state's streams, rivers, lakes, and wetlands. About 70% of Wisconsin's residents use groundwater at home, drawing nearly 535 million gallons of groundwater daily (55 gallons/person/day), and it supplies nearly one-quarter of Wisconsin's business and industrial water needs (Kassulke and Chern 2006). Irrigation equipment withdraws about 182 million gallons of groundwater per day during the growing season. Dairy and cattle farms use 100 million gallons per day. The state's total estimated supply of groundwater is approximately 1.2 quadrillion gallons (WDNR 2012e).

Geology controls the rate of groundwater movement. The size of the cracks in rocks, the size of the pores within and between soil and rock particles, and the connectivity of the pores determine the rate at which water moves into, through, and out of an aquifer. Water generally moves more quickly in coarse sand, sometimes as much as several feet per day, while it may move only a few inches in a year in fine-grained clay. Permeability in limestone and dolomite depends primarily on the size, frequency, and distribution of fractures in the rock.

Groundwater is always moving toward a surface outlet such as a lake, river, spring, or wetland. Baseflow, that part of a stream's flow provided by groundwater seeping into it, is critical to creating and maintaining aquatic habitats. Decreased baseflow results in warmer stream temperatures, degraded water quality, and less spawning habitat for fish.

Groundwater quantity is affected by precipitation, infiltration rate, topography, land use, and water use. Forests and other permanently vegetated areas slow the movement of precipitation across the land's surface, promoting infiltration into the soil. Land uses and conditions such as agricultural production (particularly where soil is heavy or compacted), recently harvested forestland, and developed land associated with large amounts of impermeable surfaces (such as buildings, streets and parking lots) tend to promote runoff rather than infiltration.

Overuse of groundwater can lower the water table (the area of saturated rock and soil). Pumping can remove water from an aquifer faster than it can be replenished, decreasing baseflow to streams and negatively impacting aquatic communities and wetlands. Groundwater use has significantly lowered the water table in several areas of the state, including Dane County, southeastern Wisconsin, central Wisconsin, and the lower Fox River valley.

Groundwater quality can be characterized by the same parameters used for lake evaluations: conductivity, alkalinity, hardness, and pH. Groundwater is affected by naturally occurring substances and may be contaminated by substances spread on or leached into the soil. Groundwater quality varies vertically and horizontally within an aquifer and over time. Once contaminated, groundwater is difficult to clean up.

Minerals existing naturally in soils and rocks dissolve in groundwater, giving it a particular taste, odor, or color. Some minerals, like calcium and magnesium, are beneficial to health. Others are undesirable, including radium, radon gas, uranium, arsenic, barium, fluoride, lead, zinc, iron, manganese, and sulfur. Natural groundwater quality varies across the state and depends on the type of minerals with which the groundwater has been in contact. The concentration of natural contaminants depends on how long groundwater has been exposed to the dissolved minerals and the rate of groundwater movement.

Groundwater contamination can be linked to land use. What goes onto the ground can seep through the soil and turn up in lakes, rivers, streams, wetlands, and drinking water. Urban activities that threaten groundwater quality include industrial and municipal waste disposal, road salting, and careless storage of petroleum products and other hazardous materials. In rural areas, animal wastes, septic systems, fertilizers, and pesticides are the primary pollution sources. Nitrate is the most commonly detected pollutant in Wisconsin's shallow aquifers. Other common pollutants found in Wisconsin groundwater include pesticides and volatile organic compounds (VOCs).

Global/Regional Context

The concentrated abundance and high quality of Wisconsin's water resources are rare on a global scale. The state's most unique aquatic characteristic may be its geographic position within both the Great Lakes and Mississippi River watersheds. Features of ecological significance associated with the Great Lakes include the cobble beach and alkaline rockshore communities; the Great Lakes beach, barrens, and dune complexes, which support endemic species; freshwater estuaries, which are especially well represented along Wisconsin's Great Lakes coasts; the Apostle Islands and Grand Traverse Island archipelagos, featuring unusual landforms and exceptional

The winged mapleleaf is a globally rare mussel that is now listed as Endangered by both state and federal governments. A significant population of this imperiled species inhabits the lower St. Croix River. Photo by Lisie Kitchel, Wisconsin DNR.

Sandspits and lagoons are characteristic features of river mouths along the Great Lakes shores. Though many such sites have been developed and destroyed, those that remain provide critical habitat for specialists and for many migratory birds. Photo by Wisconsin DNR staff.

*The fish-eating Osprey (*Pandion haliaetus*), along with the Bald Eagle and Common Loon, is one of the iconic species associated with Wisconsin's northern lakes. Photo by Len Blumin.*

examples of diverse complexes of wetland and upland vegetation; and Lake Superior itself—the world's largest freshwater lake by surface area and the second largest by volume.

The concentration of glacial kettle lakes within the Northern Highland Ecological Landscape (which includes almost all of the state's largest property, the Northern Highland-American Legion State Forest) is globally important. Some of the lake types there are rare, and many sensitive organisms are supported by the Northern Highland's waterbodies and associated wetlands (Epstein et al. 1999).

A number of state and federally listed plants are aquatic or riparian or inhabit lacustrine shores, including the U.S. Threatened dwarf lake iris (*Iris lacustris*), a plant endemic to Great Lakes shorelines, and the Wisconsin endangered Lake Huron locust (*Trimerotropis huroniana*). Wisconsin's large rivers support some of the highest freshwater mussel diversity in North America, including the Federally Endangered Higgins' eye (*Lampsilis higginsii*), winged mapleleaf (*Quadrula fragosa*), and many other rare invertebrates and fish.

Current Assessment of Aquatic Communities

Wisconsin's surface and ground waters exhibit a wide array of physical and biological conditions, which in some cases are a reflection of natural conditions and in others are the result of intentional changes in land cover, land use, and other factors. Water quality is affected by a mix of many factors, including percentage of vegetated land; percentage of impermeable surface; quality and volume of point source pollutant discharges; soil slope and susceptibility to erosion; streambank and shoreland buffering; bank trampling by grazing animals and vehicles; and nonpoint inputs of animal and pet waste, oils and solvents, and other pollutants. Wisconsin's water quality assessment process is designed to determine whether, in light of the water quality factors described above, the state's waters are in compliance with water quality standards set by the federal Clean Water Act and other programs (see "Water Quality Standards" below).

Like terrestrial systems, aquatic ecosystems are subject to simplification, fragmentation, and other changes that can degrade certain of their values. Dams fragment streams and can block movements of fish and other aquatic organisms, isolating populations and inhibiting recolonization. Other causes of aquatic habitat degradation are channelization, dredging, rip-rap, mowing or otherwise altering shoreline vegetation, installation of sand blankets, improper culvert placement, and stretches of poor water quality or abnormal water temperatures.

Monitoring is important to assess the conditions of our state's waters and detect trends over time. Data from monitoring programs are used to assess the condition of individual waterbodies, watersheds, and the state as a whole by comparing the data to established baselines or other criteria or desired management goals. This allows Wisconsin's water managers to identify correctable problems and manage the waterbodies to benefit selected aquatic species and the aquatic systems upon which they are dependent while sustaining productive human uses of waterbodies.

Monitoring, assessing, and managing the state's many water resources is a large and complex task. The data available to assess and manage the water resources of the state are often outdated. In some cases, the necessary data are nonexistent, but plans are being implemented to generate or update the needed quality-controlled assessment data (WDNR 2015i). Before discussing the current conditions of aquatic resources in the state, it is important to understand the nature of the monitoring data and the processes used to assess the conditions of Wisconsin's waters.

Water Monitoring

The state's waters are monitored and assessed on an ongoing basis, according to the Wisconsin DNR's water resources monitoring strategy (WDNR 2015g). This strategy directs

Wisconsin DNR monitoring efforts to efficiently address the existing variety of management information needs while providing adequate depth of knowledge to support management decisions.

One aspect of monitoring water resources involves the ongoing collection of water quality, biological, and hydrologic data according to specific protocols. Wisconsin DNR monitors physical, habitat, chemical, and biological parameters to establish baseline conditions and restoration goals for Wisconsin's waters. Monitoring projects are evaluated and funded based on need as demonstrated by researchers. Wisconsin's current monitoring program reflects a partnership with federal, state, and local agencies and businesses (WDNR 2015g). As of late 2015, Wisconsin DNR staff were nearing completion of an update to Wisconsin's Water Resources Monitoring Strategy (WDNR 2015j).

■ **Baseline Monitoring: Statewide.** Baseline monitoring includes three components. The first is taking measurements at trend sites—lakes and rivers monitored to track changes in biological indexes over time. The second is conducting probabilistic surveys of randomly selected wadeable streams, lakes, coastal areas, and wetlands, which are used to infer the condition of those water resource types statewide. The third component consists of reference site monitoring, which samples conditions at Wisconsin's least impacted wadeable streams and large rivers. These reference data will be used to guide the development of regionally based nutrient criteria and Tiered Aquatic Life Use (TALU) designations for Wisconsin streams and to better understand the biological variability that can occur in warmwater streams with low nutrient concentrations. Data collection includes ambient water quality data such as dissolved oxygen, pH, temperature, hardness, heavy metals, and pesticides important in understanding the assimilative capacity that is appropriate for specific receiving waters as well as habitat assessments, aquatic invasive species, and biological indicators, such as macroinvertebrates, fish, diatoms, and aquatic plants. There is an important emphasis on collection of phosphorus and stream base flow data statewide as the issues of phosphorus permit issuance, site specific permit issuance, and high capacity well permit reviews are conducted. The emphasis on biological data and background information needed to create assessment parameters to support the creation of updated designated uses and biocriteria for the state's water quality standards will result in additional monitoring requirements in future work plans.

■ **Prescribed Monitoring: Statewide and District Collaboration.** Prescribed Monitoring includes directed monitoring activities with a common purpose and a suite of standard monitoring procedures. A major goal of this monitoring effort is to coordinate water selection across disciplines (e.g., more integration between streams and lakes, water resources and fisheries) to obtain diverse data sets from the same water body (e.g., water chemistry, physical habitat, and biological data on a single lake). Field sites will vary from year to year and will be selected jointly by District and Central Office staff. In some cases, Prescribed Monitoring projects may be used for stream, river, and/or lake monitoring waterbodies individually for whole watersheds.

For those areas in the state where protection is warranted or pollutant problems are known, such as an impaired water or an existing listed watershed where a ***Total Maximum Daily Load*** (TMDL) analysis is needed, more intensive sampling will occur to verify the cause, extent, or loading rates of the pollutant or problem. Prescribed monitoring is designed to meet statewide data needs through consistent data collection schemes and generalized site selection priorities, with watershed/site selection and monitoring designs developed by Districts. Four examples of this type of work include

- targeted watershed assessments;
- directed lake assessment (including aquatic plant management and critical habitat);
- project evaluation for Section 319 (federal nonpoint source program of the Clean Water Act) funding eligibility;
- follow-up for impaired waters.

Water Databases

Monitoring and assessment results have historically been reported in Wisconsin DNR State of the Basin reports, which are used for watershed planning. Results are also summarized in the biennial Water Quality Report to Congress, required under the federal Clean Water Act (WDNR 2014e). These reports rely on data in Wisconsin's assessment databases on all state streams and lakes. Monitoring data are available via a variety of interactive mapping databases, including the Water Assessment, Tracking and Electronic Reporting System (WATERS) (WDNR 2015f), the Surface Water Integrated Monitoring System (SWIMS) (WDNR 2014c), and the Fisheries Management Database (U.S. Geological Survey Great Lakes Gap and Wisconsin DNR Fish Mapping Application; USGS and WDNR 2015). Data from all these databases (which can be accessed through the Wisconsin DNR website or by request from Wisconsin DNR, Madison) can be incorporated into an interactive mapping function on the Wisconsin DNR's Surface Water Data Viewer, also accessible through the DNR website (WDNR 2012b).

The WATERS database is the primary means of storing data for all waterbodies and watersheds in the state, including those that are on Wisconsin DNR's impaired waters list (see the "Impaired Waters" section below) and those that are recommended for addition to the list. In addition to summary information for each waterbody, the database also includes documentation of decisions regarding each waterbody and recommendations for management.

The SWIMS database is designed to hold all water and sediment chemistry, physical, habitat, and macroinvertebrate data collected by the state's water monitoring program from

1970 to the present day. These data have been used to develop a macroinvertebrate index of biotic integrity (mIBI), based upon the pollution tolerance and habitat needs of various invertebrate species (Weigel 2003). However, this database has not been used to track changes in community composition to the extent that the fish database has.

The Fisheries Management Database (FMDB) includes data on occurrence, distribution, and relative abundance from over 15,000 fish sampling sites. Data are derived from three major sources: (1) historical data collected by a variety of scientists for the period from 1900 to 1972; (2) a major survey of statewide fish distribution and abundance from 1974 to 1986 during which 50% of the geographical area of the state was systematically inventoried by the Wisconsin DNR; and (3) fish species and community surveys conducted for a variety of purposes since 1986 by Wisconsin DNR, University of Wisconsin, U.S. Geological Survey, and others. All of these data are available electronically through the USGS Great Lakes GAP and Wisconsin DNR Fish Mapping application (USGS and WDNR 2015). These data have been used to develop fish-based indices of biotic integrity (fIBI) to assess the environmental health of Wisconsin streams and rivers (Lyons 2010).

For rivers and streams, fish data are utilized for the fish index of biotic integrity, an indicator of aquatic health, to evaluate the environmental quality of the waterbody based on fish species' tolerance of temperature, oxygen content, physical habitat, and other factors. Macroinvertebrate data lead to a macroinvertebrate index of biotic integrity value, which gives an indication of the environmental quality of a waterbody based on the pollution tolerance of the macroinvertebrate organisms found there. Information used from this database include

- presence of fish and macroinvertebrate species intolerant of environmental degradation;
- species richness;
- history of extirpations;
- current status of rare species, including those listed as endangered or threatened; and
- status of natural reproduction of top-level predators.

The fish IBI and macroinvertebrate IBI scores derived from stream monitoring data can be used to assess and then classify or group rivers and streams according to management strategies. The four management strategies are (1) to consider waterbodies for ***Outstanding Resource Waters*** or ***Exceptional Resource Waters*** listing (see the "Outstanding/ Exceptional Resource Waters" section below); (2) to maintain existing conditions; (3) to implement a habitat/water quality restoration plan; and (4) to consider waterbodies that do not meet the parameters of one or more water quality elements for inclusion on Wisconsin's Impaired Waters list (see the "Impaired Waters" section below).

Water Assessment

Water quality assessments compare monitoring data to established criteria and thresholds that correspond to discrete conditions (excellent, good, fair, poor). Assessments are also designed to identify lakes and streams that exhibit very high water quality as well as identify those waters that have various forms of water quality degradation. One of the primary uses of Wisconsin's water quality assessment process is determining whether the state's waters are in compliance with the water quality standards of the federal Clean Water Act and the laws codified in state statutes and administrative code (see the "Water Quality Standards" section below under "Land Use and Environmental Considerations"). One of the main assessment tools for doing this is to assign use designations to state waters as defined by the federal Clean Water Act.

Use Designations. Assigning a use designation is one of the first steps in managing water quality in Wisconsin. Required under the federal Clean Water Act, the use designation process evaluates the resource and its natural characteristics and assigns a use designation that then requires the state to meet these water quality standards (see "Water Quality Standards" below). Wisconsin's designated uses include but are not limited to the following (WDNR 2015i):

- Fish and Aquatic Life
- Recreation Use
- Public Health and Welfare
- Wildlife

Stored monitoring data are analyzed using statistical packages that incorporate parameters outlined in the Wisconsin

What is an IBI?

An Index of Biological Integrity (IBI) is a compilation of a broad range of biological information. These data are used to develop a numerical reference that relates human influence to the biological attributes of a water body. Values or metrics that are gathered include the degree of pollution tolerance or intolerance of taxa, taxonomic composition (number and abundance of taxa), and population attributes, and community attributes (e.g., number of filter feeders). A baseline IBI value is developed for waters that are judged to be in pristine condition, and this value can be compared to values derived from data gathered at other sites to gauge the degree to which a waterbody has been altered by human actions in the watershed.

Consolidated Assessment and Listing Methodology (WISCALM). Current Use and current condition are stored in the Waterbody Assessment Tracking and Electronic Reporting System (WATERS). These data are available on interactive web-mapping applications. WisCALM is generally reviewed and updated every two years. (As of late 2015, the most recent version is WisCALM 2016; Wisconsin DNR 2015i.) The Wisconsin DNR Fisheries Management Database (FMDB) and the Surface Water Integrated Monitoring System database (SWIMS) are the primary sources of information in making this designation.

As an example, Fish and Aquatic Life use designations are assigned to surface waters after those waters are evaluated using various assessment techniques. Data are interpreted with regard to a multitude of factors that reflect the surrounding aquatic ecosystem. Most commonly, these factors dictate the use of clear guidance in merging data and professional judgments to make final decisions in assigning use designations that are appropriate to specific waters. The process of assigning use designations is detailed in *Guidelines for Designating Fish and Aquatic Life Uses for Wisconsin Surface Waters* (WDNR 2004) and the Wisconsin DNR'S WisCALM document (WDNR 2015i).

■ ***Lakes Fish and Aquatic Life Assessment:*** The Wisconsin DNR focuses on in-lake water quality metrics, especially the ***Carlson trophic state index*** (TSI) (Carlson 1977), to assess a specific lake's Fish and Aquatic Life designated use and overall water quality. A TSI value is related to biological productivity, which is in turn greatly influenced by nutrient concentrations**.** A TSI value provides a calculation based on either ***chlorophyll-a*** concentration or ***Secchi*** depth, for which Wisconsin DNR also uses satellite water clarity data as a surrogate. These satellite data may be found in map form on the Wisconsin DNR's Surface Water Data Viewer (WDNR 2012b). Because TSI is a prediction of algal biomass, typically the chlorophyll-a value is a better indicator of TSI than Secchi or satellite data (WDNR 2015i).

These in-lake parameters correlate strongly with fish and other aquatic life communities (macroinvertebrates, aquatic plants, etc.) within a lake (WDNR 2015i). High levels of nutrients can lead to eutrophication of lakes with undesirable growths and decomposition of algae, aquatic weeds, and toxic blue-green algae (cyanobacteria) blooms. This in turn limits the amount of available light to macrophytes and adversely affects other aquatic organisms. In eutrophic lakes, decaying algae and weeds use up oxygen in the water. This can lead to lowered water column oxygen levels, which can in turn cause die-offs of fish that require higher concentrations of oxygen in order to survive.

There are four ranges of trophic status (productivity) for freshwater lakes:

- ***Oligotrophic***: abundant dissolved oxygen and relatively low nutrient levels and overall productivity
- Mesotrophic: moderate nutrient levels and occasional oxygen depletion
- Eutrophic: high productivity, high nutrient levels, and complex ecosystems
- Hypereutrophic: degraded aquatic habitat with simplified communities, altered species compositions, and dysfunctional ecological processes.

TSI values range from low (oligotrophic, TSI <30) for very clear, nutrient-poor lakes to high (hypereutrophic, TSI >70) for extremely productive, nutrient-rich lakes (WDNR 2015i). Very few lakes in Wisconsin fall into the category of "very clear, nutrient-poor lakes" (though a number of these occur in the Northern Highland Ecological Landscape). The cutoff for excellent TSI values includes these clear lakes but also includes some lakes in the mesotrophic category, based on sediment core data. The sediment record indicates that some lakes are naturally more productive than others.

■ ***Stream and River Fish and Aquatic Life Assessment:*** As in many other states, the Wisconsin DNR relies on biological indicator metrics to assess water quality and evaluate fish and macroinvertebrate diversity of streams and rivers in Wisconsin. IBIs are also used to assist in the "use designation" process. These include a number of fish indices of biotic integrity (fIBI) and a macroinvertebrate index of biotic integrity (mIBI). Currently there are three different fIBIs used to assess wadeable stream condition (for the classes of cold, warm, and small warm/cool water streams) and one fIBI used to assess nonwadeable ("large") river condition.

■ **Outstanding/Exceptional Resource Waters.** Wisconsin's highest quality waters are designated as Outstanding Resource Waters (ORWs) or Exceptional Resource Waters (ERWs) using the water assessment process. These designations are for surface waters that provide "outstanding recreational opportunities, support valuable fisheries and wildlife habitat, have good water quality, and are not significantly impacted by human activities" (WDNR 2012a). Surface waters with these designations have additional protection from the effects of pollution under the Clean Water Act. Use of these designations to meet the Clean Water Act administered by the U.S. Environmental Protection Agency is to prevent lowering water quality in those waters having significant ecological or social values.

ORWs receive the state's highest protection standards, while ERWs receive only slightly less protection. ORWs and ERWs share many of the same environmental and ecological characteristics. They differ in the types of discharges each receives and the level of protection established for the waterway after it is designated. ORWs typically do not have any point sources (e.g. industrial sources or municipal sewage treatment plants) discharging pollutants directly to the water, though they may receive runoff from nonpoint sources. New discharges may be permitted only if their effluent quality is equal to or better than the water quality of that waterway when it was designated as an ORW—no increases of pollutant levels are allowed. ERWs may have existing point sources at the time of designation. Like ORWs, dischargers to ERW waters are required to maintain background water quality levels; however, exceptions can be made for certain situations when an increase of pollutant loading to an ERW is warranted because human health would otherwise be compromised.

As of 2012, out of Wisconsin's nearly 15,000 lakes and impoundments, a limited number have been evaluated for ORW/ERW status; so far 103 are designated as ORW (Table 2.5). Of Wisconsin's 53,413 perennial and intermittent streams and rivers, 2,683 streams (13,778 miles) have been assessed for water quality. Of these, 254 streams are designated as ORW, and 1,544 streams are designated as ERW. However, it can be more useful to consider stream statistics in terms of the number of stream miles rather than number of streams, since streams can be of widely varying lengths. Wisconsin has a statewide total of approximately 85,000 miles of perennial and intermittent streams. Based on the 2012 ORW/ERW list, a total of 3,100 stream miles (3.7%) have been designated as ORW, and 4,613 stream miles (5.5%) have been designated as ERW (WDNR 2012a). Water quality data for the state's streams are reviewed periodically to determine whether additional streams should be given either of these protective designations. Designation is approved and codified in the administrative rule process.

These designated waters are distributed very unevenly across the state, which may be a reflection of the differences in the dominant land uses across ecological landscapes. These waters were designated based on the best information available at the time. Wisconsin's state list was most recently updated in 2010. The designation process is conducted every two years, and additional data are gathered as resources allow.

Impaired Waters. While Wisconsin's water resource quality is generally good and improving, water assessments have shown that a number of waters have persistent water quality problems. Under Section 303(d) of the Clean Water Act, Wisconsin DNR has identified a subset of impaired waters—mostly streams and some lakes—that do not meet water quality standards for designated uses. The waters under the 303(d) designation are reviewed and updated every two years, in even-numbered years. Current impaired waters and proposed changes may be found on the Wisconsin DNR's impaired waters web page (WDNR 2015c).

Impaired waters are identified by comparing monitoring results for a waterbody to preestablished quality thresholds for specific parameters that describe conditions for the designated use in question. A waterbody is considered impaired and placed on the ***U.S. Environmental Protection Agency 303(d) list*** if it does not meet water quality standards (WDNR 2015c). A water quality standard is not met if one of the two conditions occur: either (1) the current water quality does not meet the numeric or narrative criteria or (2) the designated use that is assigned to the waterbody is not being attained (WDNR 2015i).

For example, attainment of a Fish and Aquatic Life use designation for a given stream is determined by reviewing monitoring results collected within the last five years for aquatic macroinvertebrate species and fish species. Field results are compared to expected values for analytical indices, such as the fish IBI and the macroinvertebrate IBI. When one or both of the fIBI and mIBI values for a given stream consistently show poor values over time, the water is further evaluated. Land surveys, in-stream habitat evaluations, and stream chemistry data are gathered to determine the specific pollutants and associated impairments for the stream or section of stream. This additional evaluation is necessary to differentiate "natural conditions" from those where human-induced problems affect water conditions.

If the IBIs indicate impaired waters, the Wisconsin DNR uses Total Maximum Daily Load (TMDL) analysis, which identifies the ambient concentrations of key pollutants that are impairing the water, identifies sources of that pollutant, and estimates the allowable pollutant loads for a waterbody. TMDL analyses are required for impaired waterbodies by the federal Clean Water Act and serve as a means to reduce or limit pollutant loadings so that a waterbody can meet water quality standards.

As of 2014, over 6,000 (totaling 793,898 lake acres) of the state's 15,000 lakes (which total about one million acres) have been assessed for water quality (WDNR 2014e). This represents nearly all lakes in Wisconsin larger than 10 acres but very few lakes under 10 acres. About 31% of assessed lake acres have been found to be impaired (see below). Because of their tendency to trap silt and nutrients, and other factors,

Table 2.5. *Number of Outstanding Resource Waters (ORW) and Exceptional Resource Waters (ERW) in Wisconsin, 2012.*

	ORW (No. of waters)	ERW (No. of waters)	ORW Stream miles	ERW Stream miles
Streams	254	1,544	3,179	4,668
Lakes	97	NA	NA	NA
Impoundments	6	NA	NA	NA
State total	**357**	**1,544**	**3,179 miles**	**4,668 miles**

Source: Wisconsin DNR Bureau of Watershed Management data (WDNR 2012a).

a majority of all assessed impoundment acres have water quality impairments.

Of Wisconsin's 12,600 perennial streams and rivers, 7,100 streams (35,000 miles) are included in the Wisconsin DNR's Surface Water Data Viewer (WDNR 2012b). (The majority of streams and stream miles not yet entered into the database are very small streams of short length.) About 19,624 stream miles (46% of stream miles in the WATERS database) have been assessed for water quality; of those assessed miles, about 29% have been found to be impaired (WDNR 2014e).

Current Condition of the Great Lakes

Many parts of the Great Lakes shorelines have been modified by urban, industrial, and second-home development; seawalls and jetties; and changing natural cycles of water level fluctuation. These have affected beach, dune, and coastal wetland systems as well as uplands adjoining the Great Lakes. Contaminants are commonly found in many Lake Michigan and Lake Superior fish at levels that require consumption advisories, but these contaminant levels have been declining since the 1970s, although the rate of decline has been slowing since the 1990s (Hickey et al. 2006).

Fish communities in Lake Michigan are disturbed and unstable. The lake and its biota have been dramatically affected by habitat simplification, overfishing, water quality degradation, and the introductions of invasive species, including the alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax)*, sea lamprey (*Petromyzon marinus*), and zebra mussel (*Dreissena polymorpha*). These factors have all affected fish populations and other aquatic life (WDNR 1995). Fish communities in Lake Superior, though heavily exploited, are more stable, with significant natural reproduction of most trout and salmon species, including the native lake trout (*Salvelinus namaycush*). Pygmy whitefish (*Prosopium coulteri*), a Wisconsin Special Concern species, is found in Lake Superior and is the only known U.S. population east of the Rocky Mountains.

Current Condition of Inland Lakes

The number and variety of inland lakes makes it difficult to give an overview of their condition. Local activities and conditions strongly impact lakes. More than half of Wisconsin's inland lakes could be described as having good to excellent condition based on trophic status and fish communities (WDNR 2014e). Of the more than 793,898 acres of lakes assessed for the Fish and Aquatic Life designated use (most lakes 10 acres or larger), 187,204 acres exhibit excellent water quality and are fully supporting their assessed designated uses. Another 359,606 acres exhibit fair to good water quality and are supporting their assessed designated uses. Combined, these 546,810 acres (69% of the assessed acres) of Wisconsin's lakes support or fully support the Fish and Aquatic Life designated use (Figure 2.24). The remaining 247,088 acres of assessed lakes are impaired (31%).

Current Condition of Rivers and Streams

Wisconsin rivers and streams are relatively healthy. Of the state's more than 85,000 miles of perennial and intermittent streams (both navigable and non-navigable), about 42,468 miles are entered into the Wisconsin DNR's WATERS database (WDNR 2014e). Of these, 19,624 river miles have been formally assessed for Fish and Aquatic Life use designation. Of these assessed miles, 10,299 miles with excellent water quality are fully supporting their Fish and Aquatic Life use designation, and 3,677 miles with fair to good water quality are meeting their Fish and Aquatic Life use designation. The remaining 5,648 stream miles (29% of the miles assessed) are impaired, with poor water quality (Figure 2.25).

Large rivers exhibit the highest fish species richness of all the aquatic communities, averaging 14 species per sampling station, with a range of one to 40 species (Lyons 1992). Ten

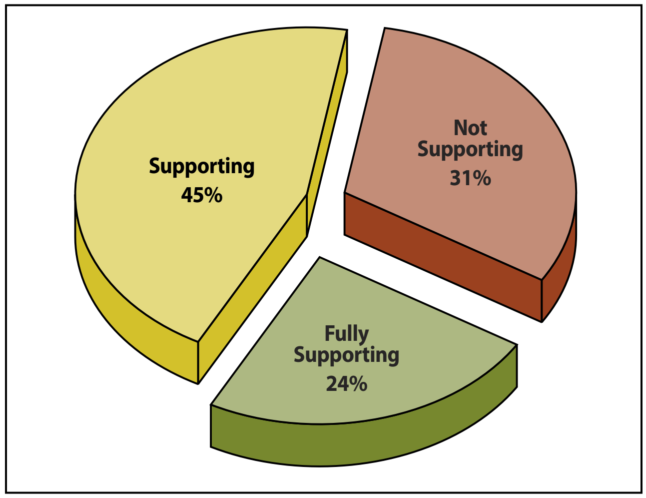


Figure 2.24. *Number of acres of Wisconsin inland lakes supporting the Fish and Aquatic Life use designation, 2014 (WDNR 2014e).*

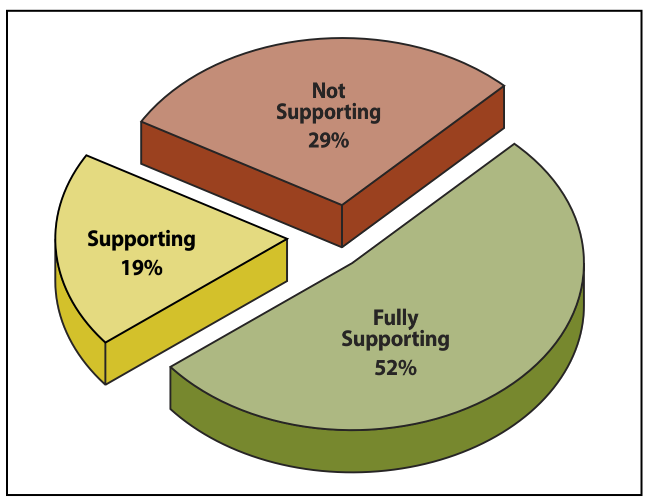


Figure 2.25. *Number of miles of Wisconsin rivers and streams supporting the Fish and Aquatic Life use designation, 2014 (WDNR 2014e).*

Wisconsin Endangered fish species and 11 Wisconsin Threatened fish species currently inhabit flowing waters (WDNR 2009d). River mussels, however, have been negatively and dramatically affected in abundance and distribution. At least two mussels, the scaleshell (*Leptodea leptodon*) and fat pocketbook (*Proptera capax*), have been extirpated in Wisconsin. Five mussels native to Wisconsin are now on the federal endangered species list: winged mapleleaf, Higgins' eye, bullhead (sheepnose) (*Plethobasus cyphyus*), snuffbox (*Epioblasma triquetra*), and spectacle case (*Cumberlandia monodonta*) (USFWS 2015a). Eleven mussel species are listed on the Wisconsin Natural Heritage Inventory (WDNR 2009d) as Wisconsin Endangered (including the five in the preceding sentence), seven are Wisconsin Threatened, and seven are Wisconsin Special Concern. This is a very high proportion of the state's total native mussel fauna (49%, or 25/51 species). Some other aquatic invertebrates are now considered rare, and several of these—a few dragonflies and two mayflies—have received legal protection.

Some stretches of the state's major rivers still show significant water quality degradation. Conditions in the Mississippi River have improved over the last two decades, primarily due to point source pollution abatement. Water quality in the Wisconsin River has improved substantially since its poorest condition in the 1950s and 1960s, but there are still problem areas, especially in central Wisconsin.

Dams continue to impact the condition and functions of rivers and streams in the state. There are about 3,800 dams on Wisconsin waterways. Nearly a third (1,160) are classified as "large dams," with a structural height of over 6 feet and impounding 50 acre-feet of water or more or having a structural height of 25 feet or more and impounding more than 15 acre-feet of water. Inspections of these large dams by the Wisconsin DNR are required once every 10 years. The federal government has jurisdiction over about 190 large dams that produce hydroelectricity, comprising about 5% of Wisconsin's dams.

Free-flowing stretches of the South Fork of the Flambeau River support especially high invertebrate diversity. Much of the river is embedded within extensive second-growth hemlock-hardwood and pine-hardwood forest. Little Falls, Flambeau River State Forest, Sawyer County. Photo by Eric Epstein, Wisconsin DNR.

Dams range from large structures on the Mississippi River built to maintain navigation channels for barges, to small water-level control structures in marshes and other wetlands. Few new dams are being built, but renovation and expansion of existing dams is common. Dams slow currents, lead to increased water temperatures, and fragment aquatic habitats, changing them from essentially riverine to lacustrine environments. These alterations, when combined with overexploitation of aquatic species, such as fish or mussels, and declines in water quality, due to the addition of toxins, sediments, or nutrients, have negatively impacted populations of sensitive aquatic species, especially mussels and some aquatic insects. A majority of all impoundments assessed in Wisconsin have impaired water quality (WDNR 2014e).

Since 1967 more than 100 dams have been removed from the state's waterways, mostly based on economic considerations. Removal has led to improved water quality, habitat, and biodiversity at many of these sites. However, there has been some interest expressed in fitting additional existing dams with electrical generation turbines, which could double the state's hydropower capacity. Operation of any new hydropower facilities would have to be closely regulated in order to prevent mortality and other damage to aquatic organism populations (Delung 2010).

Current Condition of Groundwater

Groundwater quality varies greatly throughout Wisconsin. The primary human-caused contaminants of concern are volatile organic compounds (VOCs), nitrates, and pesticides. Natural compounds that may present health concerns include iron, manganese, ***sulfate***, arsenic, and radium. Microbial contaminants (viruses, bacteria, and parasites) are increasingly becoming concerns.

Groundwater quantity and water withdrawal issues are receiving more attention. The state has limited authority to regulate groundwater withdrawals that may affect surface water resources. Excessive pumping of groundwater has occurred in parts of southern Wisconsin where baseflow of groundwater to some streams and lakes has been depleted. Where groundwater withdrawals have lowered water tables, wetlands may be damaged or destroyed.

Current Condition of Springs

Wisconsin's groundwater law has important implications for springs, yet they are poorly studied. Policy makers therefore lack information to determine the significance of the impacts of land use changes. The U.S. Geological Survey conducted a limited survey of the biological communities and physiochemical characteristics of a portion of the springs in Iowa and Waukesha counties (Macholl 2007). The study was primarily concerned with developing a methodology for collecting baseline data on springs. In examining about 20 springs in each of the two counties, the study concluded that

Iowa County, with a wealth of spring resources, has experienced minimal, if any, loss of springs over the last 50 years (as of 2007). Springs here were more likely to be vulnerable to pumping from wells along ridge tops. Iowa County springs also were observed to have good native vegetative and invertebrate communities.

In Waukesha County, which has a much higher and rapidly growing population, springs have been lost to residential and commercial development. The spring communities that remain in this part of the state are composed of higher percentages of nonnative plants. Regional pumping from high capacity wells in southeastern Wisconsin affects shallow flow patterns. Since groundwater flow occurs from the shallow bedrock downward to deeper parts of the aquifer, springs (and wetlands, streams, and lakes) in Waukesha County can be harmed by additional groundwater withdrawals from both the shallow and deep water-bearing rock layers in the region.

Issues of Composition, Structure, and Function

Many waterbodies in Wisconsin have experienced changes in their postglacial composition, structure, and function since Euro-American settlement. Primary influences related to changes in composition, structure, and function of aquatic communities in the state include hydrologic modification, water quality, species exploitation, and the introduction of nonnative invasive species. These affect community composition, structure, and function due to resultant aquatic community instability, habitat loss, loss of pollution-intolerant species, removal of the best brood stock for sport fish, and loss of rare but important species.

Composition

Aquatic species (plant, fish, invertebrate, herptile, bird, and mammal) composition of Wisconsin's waterbodies prior to Euro-American settlement is not well documented compared to modern-day inventories. Some historical accounts exist from the experiences of early explorers and the first settlers, but these records are extremely limited in scope and in scientific reliability. While some written accounts of fish species composition were recorded after the 1830s, aquatic biologists rely on records after 1900 for comparing changes in species composition over time. By comparing data from over the last century, biologists are able to document the changes that have occurred in fish species composition. From a statewide perspective, fish and other aquatic species composition has been altered somewhat, but nearly all indigenous postglacial species remain (Fago 1992, Lyons et al. 2000).

As of 2012, 149 native fish species are recognized as being established in Wisconsin (J. Lyons, Wisconsin DNR, personal communication). However, numerous waterbodies have experienced significant disruption of fish community composition as a result of pollution, habitat modification, hydrologic alteration, and/or the establishment of invasive species. Several fish species with complex life stage requirements have been extirpated from major ***stream segments*** due to dam construction and a host of other activities that impair water quality, raise water temperatures, and remove necessary habitat features.

In some cases, fish species native to Wisconsin have been introduced into waterbodies from which those species were not known, primarily with the intent of enhancing sport angling. Nonnative fish like the common carp (*Cyprinus carpio*) were introduced as food fish in the 1880s and were at first prized by immigrants from Europe. Other nonnative fish species have been introduced unintentionally. Some of these nonnative species, such as the round goby (*Neogobius melanostomus*), have displaced native species. The sea lamprey is a nonnative parasitic fish that harms lake trout and other important native species in the Great Lakes. Other nonnative fish, such as the alewife, have adversely affected populations of certain native Great Lakes species through competition for food or predation on their larvae and/or eggs (Madenjian et al. 2008). Introduction of predator fish has in some cases significantly altered forage fish populations and disrupted commercial fisheries.

Lyons et al. (2000) reported that six native fish species have been extirpated in Wisconsin: ghost shiner (*Notropis buchanani)*, ironcolor shiner (*Notropis chalybaeus)*, creek chubsucker (*Erimyzon oblongus*), deepwater cisco (*Coregonus johannae*), blackfin cisco (*Coregonus nigripinnis*), and shortnose cisco (*Coregonus reighardi*). Three of these, the deepwater, blackfin, and shortnose cisco, are now globally extinct (USFWS 2015b). Of Wisconsin's ten endangered native fish species, three species—striped shiner (*Luxilus* [formerly *Notropis*] *chrysocephalus*), pallid shiner (*Notropis amnis*), and slender madtom (*Noturus exilis*)— have declined to such a great extent that they are now nearly extirpated in the state.

Seventeen nonnative fish species are established in Wisconsin waters, including seven species reported from state waters since publication of G.C. Becker's comprehensive survey of Wisconsin's fish species (Becker 1983): kokanee salmon (*Oncorhynchus nerka*) (the lake-dwelling form of the sockeye salmon), western mosquitofish (*Gambusia affinis*), threespine stickleback (*Gasterosteus aculeatus*), white perch (*Morone americana*), ruffe (*Gymnocephalus cernuus*), tubenose goby (*Proterorhinus marmoratus*), and round goby (Lyons et al. 2000). At least 19 additional nonnative species have been reported from Wisconsin that are not currently established, including red shiner (*Cyprinella lutrensis*).

State permits and federal law regulates the intentional release of nonnative species into Wisconsin waters via ships' ballast water discharge in an attempt to minimize the potential for introducing unwanted species. However, invasive species such as silver carp (*Hypophthalmichthys molitrix)*, bighead carp (*Hypophthalmichthys nobilis*), and others have already entered state border waters via the Mississippi River drainage and pose a significant danger of entering state inland waters.

Introduced nonnative fishes and invertebrates have damaged many waterways. For example, the proliferation of rusty crayfish (*Orconectes rusticus*) has changed vegetation composition in many lakes and streams in the state. Zebra mussels and quagga mussels (*Dreissena bugensis*) have filtered excessive amounts of algae from lakes, robbing the food source of plankton vital to the base of the food web. Common carp continue to uproot native vegetation and stir up sediments, degrading habitat values and interfering with native sight-feeding predator populations.

Compared to information available on fish and invertebrates, aquatic plant community composition has not been as well documented. However, some general information is available. In the most diverse nondegraded lakes and other waters in Wisconsin, aquatic plant surveys have historically found 30 or more native species. This is still true for many lakes in the northern section of the state. However, many waters in the southern portion of the state may now support only half that number of species, due to the impacts of land use changes (WDNR 2007). Several nonnative invasive aquatic plants are now established in Wisconsin, including Eurasian water-milfoil (*Myriophyllum spicatum*), curly-leafed pondweed (*Potamogeton crispus*), and purple loosestrife. These species are well adapted to establishing themselves in areas where the native aquatic vegetation has been disturbed, and they can prevent the reestablishment of native plants. Their much lower value as habitat for aquatic invertebrates and other aquatic species, including young fish, contributes to diminished or impaired ecosystem function.

Structure

Aquatic ecosystem structure can be illustrated in part by examining major habitat components. In lakes, the major habitat components include shallow or near-shore littoral zone vegetation with emergent vegetation rooted to depths of 4–5 feet and submergent vegetation rooted to a water depth of 15 feet, depending on the degree of light penetration. Other structural features are rock shoals or reefs, wood or other organic debris, islands, bays, lakebed springs, areas of deep, cold water, and substrates of muck, ***marl***, gravel, sand, or boulders.

Vegetative structure in aquatic environments is similar in some ways to that of terrestrial environments in that it grows to a range of elevations above the bed of the waterbody but is not as diverse as most terrestrial communities. Aquatic macrophytes are plants rooted to the bottom of waterbodies. Common species include coontail (*Ceratophyllum* spp.), milfoil (*Myriophyllum* spp.), waterweed (*Elodea* spp.), and pondweeds (*Potamogeton* spp., *Stuckenia* spp.) (submerged species likened to terrestrial groundcover); and water lilies (*Nymphaea* spp.) and spatterdock (*Nuphar* spp.), bulrushes (*Scirpus* spp.), reeds (*Calamagrostis* spp, *Sparganium* spp., *Phragmites australis americanus*, and *Cinna latifolia*), sedges, wild rice (*Zizania* spp.), and cat-tails (*Typha* spp.) (emergent species likened to terrestrial overstory). These aquatic macrophytes provide habitat for aquatic invertebrates that in turn support populations of herptiles, fish, birds, and mammals. For additional information on the composition and structure of aquatic macrophyte communities, see the descriptions of Emergent Marsh, Floating-leaved Marsh, Submergent Marsh, and Wild Rice Marsh communities in Chapter 7, "Natural Communities, Aquatic Features, and Selected Habitats of Wisconsin."

In rivers and streams, habitat structure can also include areas of varying current velocity and depth (characterized as runs, riffles, and pools) and undercut banks as well as gravel, rocks, and rubble; silt deposits; overhanging streambank vegetation; and groundwater discharge zones where cold water augments stream flow.

Aquatic communities can also be examined in terms of the population structure of their constituent species. Such data are often collected for pollution-intolerant fish and can reflect both naturally occurring and human-caused changes in habitat conditions. Low overall abundance or a lack of larger individuals of some fish species may be addressed by changes in harvest regulations, habitat restoration, or proposals to modify land uses.

Groundwater "structure," while having no biological support function, could be envisioned as the geologic layers important for enabling the continual or periodic delivery of groundwater to surface water and for storing groundwater for use when pumped to the surface.

Function

The concept of ecological function in aquatic communities includes functions such as providing sufficiently aerated bottom substrate for spawning coldwater species; supporting native vegetation as habitat for many species; offering resting, nesting, and feeding habitat for migratory waterfowl; and providing host fish for transportation of native mussel ***glochidia*** (mussel larvae) throughout a river system. Rivers and streams provide the ecological function of depositing nutrient-rich sediments across floodplains. High flows can clear accumulated sediments from stream bottom sites critical to species that thrive in areas without sediment.

Emergent, floating-leaf, and submergent macrophytes help stabilize soft sediments, reduce turbidity by trapping suspended particulates, provide habitat for attached algae and bacteria that compete for the same nutrients that may otherwise fuel algae blooms, and absorb wave energy that contributes to shoreline erosion. They also serve as critical habitat for fish and other aquatic life by acting as food sources, providing spawning and juvenile rearing areas, affording camouflage and structural refuge from predators, and producing dissolved oxygen required by aerobic organisms (Garrison et al. 2005).

An example of how an aquatic ecosystem function can be disrupted is illustrated by the complex web of impacts following introduction of the nonnative zebra mussel into Wisconsin waters. Zebra mussels can occur in very high densities, and

Some waters are highly eutrophic, resulting in degraded water quality and large algal blooms. Photo by Wisconsin DNR staff.

they feed by filtering plankton from the water. They can clear the water of plankton to the point where zooplankton, forage fish, and the young of predator fish cannot obtain sufficient food to maintain their populations and individual growth. This creates a food shortage for sport fish and other predators (including some waterfowl and other waterbirds), and some species in the sport fish population can decline. However, the increased light penetration can promote increased growth of aquatic plants, thereby increasing habitat available to species such as yellow perch and northern pike (Benson et al. 2013).

Meanwhile, the zebra mussels deposit large volumes of body wastes, and certain macroinvertebrate benthic species feed on these wastes and increase their populations. Bottom-feeding fish such as drum (*Aplodinotus grunniens*), lake sturgeon (*Acipenser fulvescens*), and catfish then have more available food, and their populations can increase.

Zebra mussels also often attach themselves to native mussels, which can greatly inhibit the ability of the native mussels to obtain sufficient food and oxygen and to reproduce, causing a decline in native mussel populations.

General Influences on Aquatic Community Composition, Structure, and Function

Many of the changes to aquatic communities have affected their composition, structure, or function. Most of these are human induced. These include hydrologic and habitat modifications, water quality changes due to addition of excessive nutrient, sediment and pollutant loads, depletion of native species, and introduction of invasive nonnative species.

■ **Hydrologic Modification.** In Wisconsin, the most common forms of hydrologic modification are the large areas of impervious land cover created by urban and industrial development, construction and operation of dams, stream channelization, and the ditching of streams and draining of wetlands to facilitate agricultural use. Streams in some urban areas have been straightened and lined with concrete.

Intensive urban and industrial development includes rooftops, roads, and parking lots, which increase impervious surface area within a watershed. This in turn reduces the area of soil and vegetation for infiltration of storm water to the groundwater. Impervious surfaces are major contributors to flash flooding in streams, increasing both the severity and frequency of flooding, and quickly moving pollutants into lakes and streams. More intensive runoff reduces groundwater recharge and leads to abnormal decreases in base flows in streams during dry periods.

Construction of roads and homes is often accompanied by alterations in storm water runoff direction, content, and volume, as well as by the obliteration of ephemeral ponds. These land use practices, along with agriculture, forestry, and other activities, may disturb soil, promote sedimentation, reduce habitat for herptiles and other species, and exacerbate stream instability. Also, increased urban development and irrigation-dependent agriculture results in high volumes of groundwater withdrawal, which can lower water tables and deprive springs, streams, lakes, and wetlands of the quantities and levels of water needed to maintain plant and animal communities.

Removal or modification of headwater streams (often done via ditching as part of agricultural development) compounds downstream water volume problems by increasing the rate and magnitude of flows, resulting in streams being more prone to "flash flooding." Riparian vegetation slows and filters moving water, so its removal contributes to higher flood peaks, with the addition of more contaminants and excessive nutrients.

Dam construction creates barriers to the free movement of aquatic organisms that is vital to many species at various stages in their life cycles. Dams also alter natural flooding dynamics and sediment transport patterns and interfere with contaminant dynamics within aquatic systems. This can greatly reduce the ability of a river to both flush sediments from river channels and flood spawning marshes. Hydroelectric facilities that alter natural flows to produce electricity for peak demand periods have significant effects on downstream habitats. Many species have life cycles adapted to the annual natural cycle of rivers flows, and dams operated to meet peak electrical demands can severely disrupt this cycle.

The above actions all contribute to habitat loss or changes to water temperature. Numerous species of aquatic plants, insects, mussels, snails, reptiles, fish, and birds are now endangered or threatened, in large part due to loss or degradation of critical habitat.

■ **Water Quality.** A number of human actions, as well as some natural conditions, have affected the water quality of Wisconsin lakes and streams enough to affect composition, structure, and function. Poorly managed septic systems, manure storage facilities, and manure application practices on fields contribute excess nutrient loads to surface waters when they are flooded or fail, which can occur even under normal precipitation levels. Runoff following the application of fertilizers, herbicides, and pesticides can add nutrients and contaminants to surface and ground water, reducing water quality. Shoreland zoning regulations that require building ***setbacks*** and leaving as much vegetation as possible along the shoreline can guide development and help ameliorate nutrient problems in some lakes. Measures to minimize both urban and agricultural riparian fertilizer applications and to maximize vegetated shoreline buffer areas can help maintain or improve water quality and provide critical habitat.

Water quality is also impacted by temperature changes caused by storm water runoff, removal of bank vegetation that provided shade, and reduction of groundwater input into lakes and streams. Most fish species and many other aquatic species have a range of temperature tolerances outside of which they have a diminished ability to thrive. For example, if a coldwater stream experiences inputs of storm water runoff heated by flowing over hot pavement, a number of coldwater species may not survive in the stream segment that is warmed to a point where dissolved oxygen levels drop beyond the level fish need to survive, or on rare occasions, stream temperature may rise to exceed their temperature tolerance. Prolonged drought or a prolonged spell of hot weather can have the same result.

■ **Species Exploitation.** Past sport, commercial, and subsistence harvest of aquatic organisms has historically strained resources in some waters. Overharvest of some fish species and overstocking of top predator fish such as Chinook salmon (*Oncorhynchus tshawytscha*) has resulted in unstable fish populations in Lake Michigan. Angler overharvest has resulted in changed fish species age structure in some waters. Ongoing research in Lake Michigan and Lake Superior is helping to address information gaps and is expected to contribute to management decisions that will over time smooth out peaks and valleys in species abundance over time.

On the Mississippi River, massive harvest of native mussels, especially for the button industry from about 1890 until the 1930s, depleted populations of some species. Sixty years later, populations had rebounded when millions of pounds more were taken for Asia's cultured pearl industry. This population depletion prompted the states bordering the upper Mississippi River (Minnesota, Wisconsin, Iowa, Illinois, and Missouri) to close commercial mussel harvest in 2006 (L. Kitchel, Wisconsin DNR, personal communication).

Exploitation of turtles and frogs had posed a threat of population decline, but regulations to limit the take of turtles and to restrict and monitor the take of frogs and amphibians have been in place in Wisconsin since at least 1997 (Christoffel et al. 2001, Christoffel et al. 2002). The major ongoing threat is from fragmentation and loss of habitat from many types of land development.

■ **Species Introductions.** Eurasian water-milfoil, spiny water flea (*Bythotrephes cederstroemi*), sea lamprey, and other invasive species outcompete, prey upon, or parasitize native species. Introduction of "domestic" strains of some native species has led to reduced genetic viability of the affected populations. Introduction of predator species native to the state but not to certain waters has led to depletion or re-balancing of some fish populations in affected waters.

Issues Affecting Major Waterbody Types and Groundwater

The composition, structure, and function of Wisconsin's various types of waters have been and may continue to be impacted in various interrelated and complex ways.

■ **Great Lakes.** Slow water exchange rates are a significant issue for the upper Great Lakes. Lake Michigan has a water ***retention time*** of 99 years; Lake Superior's is 191 years. As a consequence, pollution impacts on Lakes Superior and Michigan may be long lasting and significant for many years.

The Great Lakes support primarily coldwater fish communities, but warmwater communities exist in littoral and estuarine areas, in shallow bays, and in some tributary streams. Both coldwater and warmwater fish communities are now mixes of native and nonnative species. Nonnative species have significantly altered aquatic communities, as have angler harvest and overstocking.

The shorelines and waters of the Great Lakes host huge numbers of migratory birds each spring and fall and support important wintering populations of some waterbirds (especially diving ducks), and coastal habitats support nesting populations of many species, including rarities such as the Federally Endangered Piping Plover (*Charadrius melodus*) and the Wisconsin Endangered Common Tern (*Sterna hirundo*).

Biological diversity is declining in Lake Michigan because of its long history of nonnative species being introduced into the lake, overharvest of commercially desirable predator fish, pollution, habitat simplification caused by dredging and wetland filling, and water quality declines in estuarine and nearshore littoral areas due to excessive sediment and nutrient inputs (WDNR 1995).

Lake Superior remains relatively healthy but is threatened by airborne pollutants from distant sources as well as waterborne pollutants from local sources. Lake Superior has warmed significantly in recent decades (Austin and Colman 2007), with uncertain impacts on the lake's biota.

Future problems for Lake Michigan and Lake Superior may result from the continued introductions of invasive species, overstocking of nonnative fish, development of offshore or shoreline wind energy facilities, excessive water withdrawals, altered precipitation patterns at local and watershed scales, stabilization of Great Lakes water levels, and shoreline erosion and development.

■ **Inland Lakes and Ponds.** A number of influences, both human-caused landscape changes and natural events, affect the ecological function of lakes. Some of these human actions are being addressed in some parts of the state but not in others. Human-caused factors include converting permeable land surfaces to impermeable surfaces and removing more groundwater than natural forces can replenish. Natural events such as droughts and prolonged wet periods are less predictable. Below are some factors that can affect the composition, structure, and function of inland lakes and ponds.

- Lake and pond water levels (especially in the case of seepage and drained lakes) are affected by excessive groundwater withdrawals from land uses such as agricultural irrigation. Water levels can drop when groundwater withdrawals are excessive and precipitation can't recharge the groundwater, which supplies lakes and ponds directly through springs or indirectly through stream flow. In this case, lake levels will drop.
- When wetlands and other groundwater recharge areas are replaced by impermeable surfaces, the resulting additional surface water flow can contribute to increasing lake levels and/or flood severity. The loss of surface water storage in wetlands can lead to reduced water levels in lakes supplied by streams originating in wetlands. While shoreline vegetation in seepage lakes is adaptable to and may be at least partially dependent on some water level variation, in many lakes prolonged water level changes outside of the range of natural variation to which resident species are adapted may result in loss of either shoreland or shallow water vegetation and species dependent on these habitats.
- Water level manipulations, especially those that permanently raise water levels (such as the construction of dams), result in the destruction of or damage to biologically valuable habitats such as wetlands, mudflats, sand or gravel bars, and isolated islands.
- Continued shoreline development contributes to the loss of valuable habitats for amphibians, reptiles, birds, invertebrates, small mammals and other species. Construction-related erosion; lack of agricultural, forestry, or storm water best management practices; and inadequately treated point source wastewater discharges lead to siltation and water quality degradation.
- Atmospheric sources of mercury, ***polychlorinated biphenyls*** (PCBs), and sulfuric acid have affected otherwise pristine lakes far from most human development (Webster et al. 1993).
- Inland lakes and ponds face uncertain impacts from climate change with predicted alterations in precipitation patterns. This poses the potential for more groundwater withdrawals for residential, industrial, and residential uses in the event of a shift to drier summers in parts of the state.
- Aquatic resource management is difficult where stewardship may be shared by landowners who have differing, sometimes conflicting, interests, desires, and perspectives.
- The continued spread of invasive species poses new challenges due to the likelihood of changes in vegetation and species composition and the ability of many invasive species to outcompete and crowd out native species. Invasive species (e.g., exotic fish, amphibians, or reptiles) may be introduced intentionally or inadvertently when owners either do not observe or are not aware of existing invasive species guidelines. Furthermore, if the state's climate continues to warm as forecast, there is the potential that additional invasive species not currently adaptable to state climatic conditions could become established here in the future.

Rivers and Streams. About 3,800 dams of varying sizes have been built on Wisconsin's rivers and streams. Dam construction has changed hundreds of miles of riverine habitats in Wisconsin into lake-like or reservoir habitats. Numerous dams and locks have been built across the Mississippi River to accommodate commercial traffic. Because the gradient at the sites of waterfalls and rapids make the most effective locations for hydropower generation, dams on many other rivers have submerged rapids and waterfalls that add to habitat diversity (as well as scenic beauty) on state rivers. Virtually all major Wisconsin rivers have been impacted by dam construction in some way. This has caused the loss of major fast water features and habitats on the Wisconsin, St. Croix, Chippewa, Black, Wolf, Fox, Flambeau, and Peshtigo rivers, among others, and has flooded what once was valuable shallow water habitat along the Mississippi River valley.

The other dam impacts noted in the "Hydrologic Modification" section above have altered the habitat characteristics of hundreds of other streams, large and small, across the state. In addition, improper placement or other design shortcomings of road culverts creates barriers to the free movement of aquatic organisms that is essential to many species at various stages in their life cycles.

The structure, function, and composition of rivers and streams of all sizes have been altered by channelization, dredging, and rip-rapping. Clearing of woody debris from streams for recreation and other purposes has diminished habitat for many aquatic organisms, including invertebrates and fish. Some streams are still affected from streambank gouging during log drives during the Cutover era. Also, the recent widespread proliferation of high capacity wells in shallow aquifers for irrigation, municipal, and industrial uses has created some areas of serious depletion of groundwater levels and stream flows.

Groundwater. Groundwater may be affected by naturally occurring or human-produced contaminants. Common sources of human-caused contamination include road salt, petroleum storage, animal waste, septic systems, fertilizers, and pesticides.

Groundwater withdrawal for agricultural and commercial uses and increased demand for domestic uses has produced substantial declines in groundwater levels in areas that include the lower Fox River valley, southeastern Wisconsin, and parts of Dane County. When deep groundwater tables are lowered, it permits oxidation of naturally occurring arsenic, allowing it to enter the water and pose a health hazard. A switch from groundwater to use of surface water from Lake Michigan achieved a degree of water table recovery in a part of the lower Fox River valley.

Lowered water tables can have major impacts on wetland vegetation, in some cases effectively destroying it. In the past, this was deliberate because the intent was to convert the land from natural vegetation to cropland. Lowered water tables can lead to the oxidation of some organic soils (e.g., mucks), reducing or eliminating their capacity to support native wetland vegetation and also limiting the time over which they are productive for agricultural use.

Groundwater withdrawals may reduce the output of springs and seepages, altering the quality and quantity of water received by lakes and streams. Important microhabitats supporting habitat specialists may be destroyed. Spring protection in the southern half of Wisconsin may be especially important in light of the high level of agricultural, residential, and industrial development on the landscape that impacts spring recharge and discharge areas. Springs are important ecological and cultural features no matter where they occur, and they merit strong protection.

Land Use and Environmental Considerations

Several factors regarding land use and the environment should be considered when planning management of aquatic resources. These include requirements of the laws for the protection and management of aquatic resources as well as issues such as urbanization and development, siting of associated infrastructure, recreation, fish stocking and harvest, herptile harvest and roadway mortality, and invasive species.

Laws

Wisconsin surface and ground waters are managed and protected under a variety of federal, state, and municipal regulations. Under Wisconsin law (ch. 281, Wis. Stats.), the Wisconsin DNR is the central unit of government to protect, maintain, and improve the quality and management of the waters of the state: ground and surface, public and private. Most of these laws are implemented at least in part through management of land uses that impact water quality and quantity.

■ **Water Quality Standards.** The federal Clean Water Act requires that states adopt water quality standards to protect waters from pollution. These standards set the water quality goals for lakes, rivers, or streams by stating the maximum amount of a pollutant that can be found in the water while still allowing it to be used for fishing and swimming and allowing desirable aquatic organisms and wildlife to thrive. Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of three basic elements (WDNR 2015i):

- Goals for a waterbody classified by designating its use (e.g., Fish and Aquatic Life, Recreation, Fish Consumption use designations) according to the federal Clean Water Act
- Water quality criteria to protect or attain designated uses (numeric pollutant concentrations and narrative requirements)
- An anti-degradation policy to maintain and protect existing water quality that allows the designated uses.

The Wisconsin DNR is authorized to establish water quality standards that are consistent with the federal Clean Water Act through Chapter 281 of the Wisconsin Statutes. These water quality standards are explained in detail in Chapters NR 102, NR 103, NR 104, NR 105, and NR 207 of the Wisconsin Administrative Code. Wisconsin's water quality assessment process (see "Assessment of Current Conditions," above) is designed to determine whether the state's waters are in compliance with these water quality standards.

■ **Groundwater Laws.** Wisconsin began the protection of groundwater in the state in 1936 with the adoption and implementation of a law that required wells to be properly installed and maintained. Today Wisconsin is recognized as a national leader in well protection. Wisconsin's well and pump code, (NR 812, Wis. Adm. Code) is administered by the Wisconsin DNR. The well code is based on the sound premise that if a well and water system is properly located, constructed, installed, and maintained, the well should provide safe water continuously without the need for treatment. Most county zoning and public health offices have a copy of the well code, and it can also be found on the Wisconsin DNR's website.

Wisconsin's Comprehensive Groundwater Protection Act, Wisconsin Act 410, was signed into law in 1984 and created Chapter 160 of the Wisconsin Statues. Chapter 281 of the Wisconsin Statutes also contains provisions pertaining to the removal of water by high capacity wells. The major program components include the following:

- State groundwater standards (Ch. NR 140, Wis. Adm. Code). Once groundwater quality standards are established, all state agencies must mandate their regulatory programs to comply.
- Groundwater protection
- Design and implementation of a groundwater monitoring program (s. 160.27, Wis. Stats.)
- Establishment of a groundwater research program
- The Groundwater Coordinating Council to help with coordinating nonregulatory programs and exchanging groundwater information
- Clarified powers and responsibilities of local governments to protect groundwater in partnership and consistent with state law.

Groundwater Regulatory Approach

A two-tiered groundwater standard is a groundwater quality protection mechanism comprised of "enforcement standards" and "preventive action limits." Enforcement standards are set at numeric levels adequate to protect public health and welfare, based on scientific studies of potential health and toxicological impacts of each substance (pesticides, bacteria, industrial contaminants, etc.) under consideration. The enforcement standard represents concentrations that are assumed to be safe to consume in drinking water without causing adverse health or aesthetic concerns. Preventive action limits are specified for the same parameters but are established at lower concentrations than the enforcement standard and can be used as triggers for early evaluation of potential groundwater contamination. Preventive action limits are generally set at either 50%, 20%, or 10% of the enforcement standard, depending on what is known or suspected about the source.

Chapter 160 of the Wisconsin Statutes created the foundation for Wisconsin's groundwater quality program by expanding the legal, organizational, and financial framework to control groundwater pollution. Chapter 160 provides a multi-agency comprehensive regulatory approach, using two-tiered numerical standards, based on the premise that all groundwater aquifers in Wisconsin are entitled to equal protection. Once groundwater quality standards are established, all state agencies must manage their regulatory programs to comply. Chapter 281 of the Wisconsin Statutes also contains provisions pertaining to the removal of water by high capacity wells.

The federal Safe Drinking Water Act moved proactive public water protection forward by enabling states to implement a source water protection (SWP) program. The Wisconsin DNR is the lead state agency for Wisconsin's SWP program. The specific goal of Wisconsin's program is to achieve groundwater pollution prevention in public water supply source water areas consistent with the state's overall goal of surface water and groundwater protection. For groundwater systems, a wellhead protection (WHP) plan is required for new ***municipal wells***. A WHP plan is voluntary for any public water supply well approved prior to May 1, 1992. The Wisconsin DNR promotes and encourages WHP planning for older wells through a public information effort aimed at encouraging water utilities to protect their water supplies from potential sources of contamination.

When reviewing high capacity well applications, Wisconsin DNR considers impacts to all waters of the state including streams, lakes, wetlands, municipal wells and ***private wells***; ***cumulative impacts*** of the proposed well along with other wells on the same property; and water withdrawals on other nearby high capacity well properties. If significant impacts to waters of the state are likely, the DNR works with the owner or applicant to modify the approval to reduce the potential impacts to an acceptable level or, if such modifications are not feasible, the application would be denied. The primary framework for review of high capacity wells has been established through the 2004 adoption of 2003 Wisconsin Act 310, the July 2011 Wisconsin Supreme Court decision in the Lake Beulah case, and a September 2014 administrative law decision in the Richfield Dairy case. Formal environmental review, consistent with Wisconsin ***Environmental Analysis*** and Review Procedures, ch. NR 150, Wis. Adm. Code, is generally required in the following situations:

- A proposed well is located within a ***groundwater protection area*** (i.e., within 1,200 feet of a trout stream, outstanding resource water, or exceptional resource water).
- A proposed well could have a significant impact on at least one cubic foot per second
- A proposed well would be used such that over 95% of the water withdrawn from the well would be lost from the major water basin in which the well is located.

In these cases, conditions must be included in the high capacity well approval to ensure that the well does not result in significant adverse environmental impacts.

Nonpoint Source Pollution (Runoff Management) Rules. The legislature directed the Wisconsin DNR to create administrative rules establishing runoff management performance standards to control pollution from agricultural, urban, and transportation areas; describe implementation strategies; and lay out grant procedures to provide cost sharing for implementation. The DNR promulgated the performance standards under ch. NR 151, Wis. Adm. Code, in 2002.

The agricultural performance standards are minimum expectations that apply to all Wisconsin farms and include the following:

- Tillage setback: A setback of 5 feet from the top of a channel of a waterbody for the purpose of maintaining stream bank integrity and avoiding soil deposits into state waters. Tillage setbacks greater than 5 feet but no more than 20 feet may be required if necessary to meet the standard. Harvesting of self-sustaining vegetation within the tillage setback is allowed.
- Phosphorus index (PI): A limit on the amount of phosphorus that may run off croplands as measured by a phosphorus index with a maximum of 6, averaged over an eight-year accounting period, and a PI cap of 12 for any individual year. The Phosphorus Index took effect on July 1, 2012, when the U.S. Environmental Protection Agency approved Wisconsin's program to reduce phosphorus levels in the Great Lakes and Wisconsin's inland waters.

- Process wastewater handling: a prohibition against significant discharge of process wastewater from milk houses, feedlots, and other similar sources.
- Meeting TMDLs: A standard that requires crop and livestock producers to reduce discharges if necessary to meet a load allocation specified in an approved Total Maximum Daily Load (TMDL) by implementing targeted performance standards specified for the TMDL area using best management practices specified in ch. ATCP 50, Wis. Adm. Code. If a more stringent or additional performance standard is necessary, it must be promulgated by rule before compliance is required.
- Sheet, rill, and wind erosion: All cropped fields shall meet the tolerable (T) soil erosion rate established for that soil. This provision also became applicable to pasture lands starting in 2012.
- Manure storage facilities: All new, substantially altered, or abandoned manure storage facilities shall be constructed, maintained, or abandoned in accordance with accepted standards, which includes a new margin of safety. Failing and leaking existing facilities posing an imminent threat to public health or fish and aquatic life or violate groundwater standards shall be upgraded or replaced.
- Clean water diversions: Runoff from agricultural buildings and fields shall be diverted away from contacting feedlots, manure storage areas and barnyards located within ***water quality management areas*** (300 feet from a stream or 1,000 feet from a lake or areas susceptible to groundwater contamination).
- Nutrient management: Agricultural operations applying nutrients to agricultural fields shall do so according to a nutrient management plan. This standard does not apply to applications of industrial waste, municipal sludge, or septage regulated under other Wisconsin DNR programs provided the material is not commingled with manure prior to application.
- Manure management prohibitions:
  - no overflow of manure storage facilities
  - no unconfined manure piles in a water quality management area
  - no direct runoff from feedlots or stored manure into state waters
  - no unlimited livestock access to waters of the state in locations where high concentrations of animals prevent the maintenance of adequate or self-sustaining sod cover

Nonagricultural performance standards include

- developing and implementing plans to meet performance standards for construction site erosion and sediment control and post-construction storm water management;
- municipal implementation of public information and education programs to promote citizen involvement and understanding of residential pollution prevention;
- limiting the use of turf and garden fertilizers on large properties to that which is needed to maintain healthy vegetation; and
- municipal pollution prevention efforts to reduce total suspended solids in storm water runoff.

Protection of Isolated Wetlands (Including Ephemeral Ponds). Changes at the federal level due to a 2001 U.S. Supreme Court decision created concern about the loss of protection of "isolated wetlands," including ephemeral ponds, which are not hydrologically connected to federal navigable waters. These habitat features were formerly regulated by the U.S. Army Corps of Engineers under the federal Clean Water Act. In Wisconsin, there are at least one million acres of these wetlands, including sedge meadows, shallow marshes, and seasonal wetlands, that are some of the most productive in providing waterfowl and amphibian habitat, storing flood waters, and helping protect water quality.

The Wisconsin legislature reaffirmed the importance of state protection for these isolated or "nonfederal" wetlands, within the state's responsibilities under the Clean Water Act, in order to protect wetland water quality. The legislature passed Act 6 in 2001 to provide a degree of state protection to these wetlands. This places ephemeral ponds and other isolated wetlands in Wisconsin under the same protection that the federal Clean Water Act provides for other wetland types. The law did not impose any new regulations on landowners, but it did allow the state to continue following the same process that was used throughout the 1990s to decide whether a project that potentially affects wetlands can proceed.

In 2012 the Wisconsin legislature passed Act 118, which created wetland regulation for all wetlands in the state and no longer distinguishes federally protected wetlands from non-federally protected wetlands. The wetland permit process now requires a wetland general permit or individual permit for all wetland impacts instead of a water quality certification. The 2012 wetland law still includes a review of a wetland permit application for any proposal to fill a wetland if the wetland fill requires a environmental impact review under the Wisconsin Environmental Policy Act. Such a permit may also require a 30-day public notice, depending on circumstances prescribed in the law.

One of the problems with protecting ephemeral ponds is that it is difficult to map them in the Wisconsin Wetland Inventory as they are often very small and can be hidden in a matrix of forested vegetation or agricultural land. They are often difficult for nonexperts to identify on the landscape, especially when they are in their "dry" phase. It is therefore easy to overlook them as surface waters or wetlands when planning development projects such as transportation corridors or residential expansion. A critical first step in protecting ephemeral ponds is to develop an accurate, geo-referenced, and relatively comprehensive inventory of this resource (WDNR 2009a).

Urbanization and Development

Storm water runoff in urban and developed areas is an important consideration for management of Wisconsin's aquatic resources. Rainfall runs off paved or other impervious surfaces directly into surface water rather than infiltrating through intact vegetation and the soil to groundwater. Groundwater supporting the flow of streams (baseflow) decreases, and the flow for some streams and lakes may reverse and even recharge the groundwater. This is currently happening in Dane County where water is being drawn into the aquifer from Lakes Mendota and Monona. Increasing runoff also raises surface water temperature and water levels. Stream levels respond more quickly to rainfall events, becoming prone to flash flooding, causing street closures, property damage, and other problems.

Recreation

Recreational use of Wisconsin's lakes and rivers is another consideration for aquatic resource management planning. Second home and other development within a lake's watershed creates increased storm water runoff and can negatively impact lakes and rivers. Development around lakes (e.g., piers, sand blankets, and seawalls) can lead to loss of habitat for wildlife, fish, and other aquatic organisms. Motorized watercraft can uproot aquatic vegetation and suspend sediments in the water column, disrupting the aquatic plant community and the aquatic organisms that depend on them. Also, conflicts can occur between recreational users, such as pleasure boating or water skiing and fishing.

Recreational fishing from Wisconsin's large fishing public (among the five largest in the nation) creates demands for intensive fishery management and more access to water. Also, boats and boating can directly impact habitat with discharge of raw fuel, oils, and combustion by-products. Heavy boat traffic disturbs vegetation and macroinvertebrate production and causes shoreline erosion and sediment resuspension. Boat traffic can also disturb waterfowl and other aquatic wildlife and transport and spread invasive species.

Fish Stocking and Harvest

Aquatic resource managers have stocked fish from hatcheries and from other waters to supplement native populations to improve anglers' catches, restore depleted fish populations, and reestablish fish populations that have been extirpated in some waters. There is growing evidence that fish stocking, moving species of different genetic strains to new waters within the species' overall range (transfers), and new species introductions have long-term negative impacts on the growth, survival, reproduction, and health of both native and previously stocked fish. Release of bait fish and macroinvertebrates is also a source of genetic mixing for those species (Sheridan 1995).

Sport, commercial, and subsistence harvest of some aquatic organisms is substantial. Regulated sport angling can sometimes affect the relative abundance of older, larger fish by removing them in disproportionately large numbers.

Herptile Harvest and Roadway Mortality

Herptile harvest has reduced populations of some species. In the past, the Wisconsin Threatened wood turtle (*Glyptemys insculpta*) has been popular for the pet trade, and large common snapping turtles (*Chelydra serpentina*) were overharvested for meat. Current harvest regulations appear to be succeeding (Christoffel et al. 2002) in helping stabilize herptile populations, although some poaching reportedly still occurs. Roadway crossing deaths in some locations appear to be suppressing local populations, and various protective wildlife crossing designs of highways are being proposed for an increasing number of projects by the Wisconsin Department of Natural Resources and the Wisconsin Department of Transportation, with the goal of reducing roadway deaths of wetland and other species.

Proliferation of Exotic Invasive Species

More than 140 exotic aquatic organisms of many kinds have become established in and around the Great Lakes region since Euro-American settlement began. In addition to the well-known zebra mussel, quagga mussel, and sea lamprey, invasive species include fish such as the common carp, round goby, ruffe, and white perch; crustaceans, including the rusty crayfish and spiny water flea; and plants such as curly-leaf pondweed, common reed (*Phragmites australis*), narrow-leaved cat-tail (*Typha angustifolia*), Eurasian water-milfoil, flowering rush (*Butomus umbellatus*), and purple loosestrife. As of 2015, Eurasian water-milfoil has spread to at least 730 inland lakes, rivers, and streams in 70 Wisconsin counties

The invasive Eurasian water-milfoil has spread to many waterbodies in Wisconsin and can become thick mats displacing native vegetation. Photo by Wisconsin DNR staff.

(WDNR 2015b). For more information about aquatic invasive species, see the Great Lakes Information Network web page on invasive species (GLIN 2015).

The common practice of disposing of unused earthworms used as bait by fishermen around lakes and streams has facilitated the invasion of large areas of mesic hardwood forest in Minnesota, Wisconsin, and Michigan by these exotic organisms (no earthworms are native to the parts of the Upper Midwest that were covered in ice during the last glacial period). Establishment of exotic earthworm populations can have devastating impacts on forest soil structure, native understory plants, and ground-dwelling animals (Bohlen et al. 2004, Frelich et al. 2006, Holdsworth et al. 2007, Nuzzo et al. 2009).

Statewide Ecological Opportunities

In 2001 a Wisconsin DNR State of the Basin report was completed for each of Wisconsin's basins, describing goals, objectives, and recommendations for preservation and enhancement of the state's land and water resources. Ongoing updates to basin plans are posted on the Wisconsin DNR's watershed planning web page (WDNR 2014d). Basin plans can be integrated in those instances in which multiple basins contribute water to a major river (such as the Mississippi, Wisconsin, Fox, or Chippewa rivers) or a Great Lake.

Application of management opportunities in the individual ecological landscape chapters in this publication, along with the recommendations in the basin plans, can improve aquatic communities and the surrounding lands that impact them. The state's water basins and ecological landscapes are graphically represented on a map entitled "Water Basins" in Appendix G, "Statewide Maps," in Part 3 of the book ("Supporting Materials").

Below are some general statewide management opportunities for aquatic ecosystems that may apply to most ecological landscapes. See the individual ecological landscape chapters in this publication for more detailed management opportunities for aquatic ecosystems.

Aquatic and Hydrologically Dependent Features of High Ecological Value

A number of specific occurrences of aquatic communities and features, as well as other water-dependent communities and habitats that natural communities support, merit special management attention, which may be due to rarity, such as undeveloped lakes larger than 50 acres; the fact that certain habitats support populations of Species of Greatest Conservation Need or a highly diverse assemblage of species; the need to protect rare or sensitive aquatic features and associated wetlands of exceptional quality; the need to protect waters of exceptional purity; or for other reasons. Hydrology-dependent features of high ecological value that may warrant special management attention include the following:

- Aquatic or hydrology-dependent features associated with lakes, streams, or groundwater seepage include fens, sedge meadows, marshes, bogs, swamps, wild rice beds, headwater areas, springs, riverine lakes, and groundwater recharge areas. These have distinctive attributes and may support specialized, sensitive aquatic organisms. Even though some hydrologic features may be small in size, they often help support larger ecosystems and may provide habitats not available elsewhere.
- The Wisconsin DNR's State Natural Areas (SNA) program has identified (through field inventory) and designated a number of lakes, streams, and springs across the state and incorporated them into the SNA system. In general, these waterbodies are in an undeveloped and unaltered condition. Some are selected because they support rare species, contain an exceptionally high diversity of aquatic and wetland species, or are associated with undisturbed natural communities. Large lakes and many types of rivers and streams are underrepresented in the State Natural Area system because of the difficulties inherent in offering adequate levels of protection to large waterbodies or of finding them in a relatively undeveloped and undisturbed condition. Innovative approaches are needed to develop more effective conservation of large aquatic ecosystems, especially since large rivers in particular are among the most diverse waterbodies in Wisconsin and the Upper Midwest.
- The Wisconsin Wildlife Action Plan (WDNR 2005) has an aquatic component and identified a group of aquatic animals as Species of Greatest Conservation Need (SGCN). Aquatic habitats were also identified and, where possible, linked as habitats of importance to aquatic SGCN. Aquatic "Conservation Opportunity Areas" have been identified as a follow-up to the Wisconsin Wildlife Action Plan (WDNR 2008). These are geographic areas centered on waterbodies of especially high value to aquatic SGCN.

*The paddlefish (*Polydon spathula*) is a big river species found mostly in the lower stretches of the Wisconsin, Chippewa, and St. Croix rivers as well as in the Mississippi River. It is a "Species of Greatest Conservation Need" and also listed as Wisconsin Threatened. Illustration by Timothy Knepp.*

- The Lake Superior National Estuarine Research Reserve (NERR) has been established in the St. Louis River Estuary on Lake Superior under the direction and guidance of the National Oceanographic and Aeronautic Administration. Major partners include the University of Wisconsin Extension System, Wisconsin DNR, Minnesota DNR, University of Minnesota-Duluth, St. Louis River Citizens Action Committee, the City of Superior, and the Great Lakes Indian Fish and Wildlife Commission. This reserve features extensive diverse wetlands and boreal forest along the largest U.S. tributary to Lake Superior. It was chosen as an excellent location for strong estuarine research and educational programs. This is the only NERR on Lake Superior and is only the second to be designated anywhere in the inland waters of the United States. Designation of this research site is a project of the Wisconsin Freshwater Estuary Initiative, a partnership among state and federal agencies and programs (UWEX 2008).
- "Important Bird Areas" (IBAs) have been identified across the state (Steele 2007), and several Wisconsin IBAs focus specifically on birds and water. This subset of IBAs includes heavily used migration corridors, island rookeries, and areas supporting annual concentrations of water-dependent birds, which are used for breeding, during migration, or as wintering areas.
- Several nongovernmental organizations (NGOs) active within Wisconsin have developed projects that focus on waterbodies and associated aquatic biota and wetlands. An example is the Mukwonago River Watershed Project, a cooperative venture between the Wisconsin Chapter of The Nature Conservancy, several other NGOs active in southeastern Wisconsin, and the Wisconsin DNR to protect one of southern Wisconsin's most diverse stream systems. The Nature Conservancy has also worked with governmental and tribal partners and many private landowners and businesses to secure protection for some of Wisconsin's most important aquatic features and associated habitats in northern Wisconsin.

The Common Tern is now listed as Wisconsin Endangered. Several important breeding colonies and feeding areas occur on the Great Lakes. Photo by Len Blumin.

Identifying Biologically Significant Streams and Other Waters

There are numerous opportunities to manage and protect high quality waters in Wisconsin. Many are outlined in the individual ecological landscape chapters, and new opportunities can be identified through basic field inventory and the analysis of water quality and habitat data. Research in Wisconsin has shown that watersheds, and especially lakesheds, respond predictably to levels of both shoreland and overall watershed development. The best water quality can be found in watersheds that maintain the lowest levels of impermeable land cover and the highest levels of forest or other permanent vegetation cover. Some opportunities for identifying biologically significant aquatic resources include the following:

- Applying a fish index of biotic integrity (fIBI), a macroinvertebrate index of biotic integrity (mIBI), and a physical habitat rating (HR) to more of the watershed's lakes and streams through a combination of monitoring and assessment work. Sampling for fish species that are intolerant of pollution or habitat degradation and for the presence of rare aquatic species can enhance the Wisconsin DNR's ability to identify those waters of highest quality and sensitivity that should receive priority for protection.
- Developing methodologies similar to those that have been successfully used elsewhere. Indiana, for example, designates a "sensitive stream" as one that has been rated as high quality according to the presence of fish, macroinvertebrate, or habitat indicators and is within a subwatershed with less than 10% impervious cover.
- Evaluating baseline water quality monitoring data and continuing to incorporate biodiversity criteria, habitat indices, and supporting databases for aquatic systems.
- Collecting additional inventory information for less well-studied aquatic features such as springs and spring ponds and poorly known but potentially sensitive taxa groups to better enable the identification of those of special ecological significance.
- To protect and conserve ephemeral ponds, obtaining information that improves our understanding of ephemeral pond ecology, including their role in supporting wildlife dependent upon them.
- Identifying and documenting other ecosystem functions provided by ephemeral ponds and developing management and conservation guidelines.

Opportunities for Protecting Habitat and Water Quality of Lakes and Streams

High quality, secure, diverse habitats are needed to accommodate all life history stages of the many organisms dependent on or associated with aquatic communities. Aquatic vegetation, including emergent, floating-leaved, and submergent plants, forms the foundation of diverse and sustainable aquatic ecosystems in rivers, streams, lakes, and ponds. Aquatic plants protect water quality and produce life-giving oxygen. Aquatic plants constitute a filtering system, helping to clarify water by trapping sediments and absorbing nutrients like phosphorus and nitrogen that could stimulate algal blooms. Plant beds stabilize soft lake and river bottoms and reduce shoreline erosion by reducing the energy of waves and current. Habitat protection and restoration is therefore vital to sustaining aquatic ecosystems.

However, even the highest quality habitat alone cannot sustain healthy and diverse aquatic communities. For the many species that are intolerant of poor water quality, clean water must be considered a critical aspect of aquatic habitat.

Stream habitat surveys, conducted primarily by Wisconsin DNR fisheries staff, have shown that many opportunities remain to protect high quality waterbodies and to restore or improve waterbodies that have been degraded by factors such as excessive nutrients, chemical pollutants, trampling of streambanks by grazing animals, or removal of lakebed vegetation by riparian homeowners. The significant progress made in this area in recent decades may provide case studies for improving the success of aquatic habitat restoration efforts. Habitat and water quality can generally be improved together through a number of techniques that can be applied to waterbodies statewide. Some opportunities to protect and improve habitat in lakes and streams are as follows:

- Removing selected dams and drop structures can help reduce habitat fragmentation, improve in-stream habitat and water quality, and partially restore the natural hydrologic regime of streams.
- Implementing invasive species monitoring and control programs can help identify and perhaps minimize disruptions to native aquatic communities in lakes and streams of all types. Such programs could evaluate the potential for invasive species to colonize areas above or below dam removal sites.
- Attaching a ***Critical Habitat Designation*** to sites that meet the criteria for having high value native plant assemblages is an important means of protecting aquatic plant communities from degradation caused by human activities. This protective designation can be applied to prevent disturbance to all significant and healthy aquatic habitat areas as well as sites in need of restoration.
- Past habitat development projects targeting game fish species should be evaluated for impacts to nongame, threatened or endangered species, aquatic habitats, and ecological benefits. As warranted, improvements could be incorporated into future projects where these rare species exist and where there is good potential for maintaining them. At the same time, the potential impacts to currently common species should be evaluated to avoid undue depletion of their populations.
- Habitat restoration projects can improve natural reproduction of native fish species such as brook trout (*Salvelinus fontinalis*), walleye (*Sander vitreus*), and muskellunge (*Esox masquinongy*). This may benefit many other organisms inhabiting coldwater, coolwater, and warmwater systems and reduce the need for costly stocking.
- The adequacy of existing fishery area project boundaries in protecting water quality and important associated habitats should be evaluated. As studies indicate, protection boundaries could be increased and additional acquisition goals established to adequately protect springs, high quality streams, and associated watershed lands.
- Movement along stream corridors is essential to enable some species access to the range of habitats required by their life stages and seasonal habitat needs. Existing public and private lands along river corridors and floodplains can be managed to improve habitat connectivity and facilitate the dispersal and migratory movements of aquatic and terrestrial species. The state's river protection planning and management grants program (WDNR 2015d) may be beneficial in meeting this goal, with its funding of river management plans, development of land and river use ordinances, and land acquisitions.
- High priority coldwater streams can be kept free of beaver dams, consistent with the state's Beaver Management Plan (WDNR 1990). At the time of this writing, the Beaver Management Plan is undergoing review and revision (WDNR 2015h). Adjacent uplands could be managed in a way that does not encourage high American beaver populations and the need for constant removal.
- Erosion-prone roads at stream crossings should be inventoried and repaired. Wisconsin DNR water resources staff could work with DNR regional Environmental Analysis staff as well as state and local roads program staff (Wisconsin Department of Transportation Liaison and Local Roads) to ensure that culverts and bridges do not impede movement of aquatic life.
- Protection of aquatic resources should be increased by limiting potentially destructive uses of rivers by activities such as gravel mining.
- Known major spawning sites can be located and protected for all fish species that may be vulnerable to habitat changes. As needed, agreements could be secured with local land use planners, land managers, and public and private landowners to protect ecologically important sites from excessive siltation, runoff, vegetation removal, bulkhead construction, and other harmful actions.

- Regulatory, watershed management, land acquisition, easement, and financial assistance programs can help prevent further loss of habitat, water quality, and water quantity in lakes and streams. Some of these programs may offer opportunities for improving their ecological effectiveness as the programs are implemented and evaluated.
- In areas where agricultural land uses are prevalent, opportunities exist to achieve full compliance with animal waste management rules (currently NR 151 and NR 243, Wis. Adm. Code) to prevent nutrient pollution and streambank damage.
- Incentive programs for habitat protection or improvement (e.g., Conservation Reserve Program, land trusts, etc.) can be promoted in cooperation with other agencies, NGOs, and local governments and institutions that are preparing comprehensive plans based on the "ecosystem management decision model" or a similar framework (WDNR 1995).
- A number of state water-related grants provide opportunities for citizen groups, local governments, and others to help improve the status of Wisconsin's waters. These can be used to assist landowners who desire to improve water quality and address aquatic management problems.

Opportunities for Dam Removal and Reducing Impacts of Existing Dams

Beginning in the 1830s, Euro-American settlers and their descendants built more than 4,700 large and small dams on Wisconsin rivers and streams (about 3,800 remain in place). The early dams served to generate mechanical power for grist mills and, later, for electrical power for industry as well as provided water storage for transporting logs, created storage reservoirs for generating electricity during normal low stream flows, and retained storm flows for flood control. However, most of these dams also created ecological problems on rivers and streams.

Wisconsin has had an active dam inspection and removal program for several decades. More than 900 dams have been removed over time (including 100 since 1967 for public safety reasons), restoring flow to significant stretches of stream habitat (WDNR 2009b). About 20% of all dams built in the North Central Forest and Forest Transition ecological landscapes have now been removed. Fewer than 10% of the dams in the Western Coulees and Ridges Ecological Landscape (many of them small check dams on intermittent streams) have been removed.

Across the state, there are hundreds of opportunities to remove dams or change dam management to obtain significant habitat and biodiversity benefits, including the following:

- Dams that might be scheduled for removal should be prioritized. However, due to the diversity of the stream types that remain dammed, it is not easy to evaluate which dams would be the highest priorities for removal. As a rule, streams with high or otherwise significant biological diversity in their upstream or downstream free-flowing sections and dammed tributaries to streams that already hold high aquatic community diversity are sometimes better candidates for restoration than other streams.
- Under federal regulations, dam owners and managers must now give equal consideration to natural resources and power generation. Through the Federal Energy Regulatory Commission dam relicensing process, a number of larger hydroelectric dams have been changed from "peaking" to "run of the river" operations, resulting in fewer impacts to fish and other aquatic species.
- Coordination between local storm water authorities and other entities can enhance habitat improvement potential of flood control projects to make up for the perceived loss of flood protection after dam removal.

Opportunities for Protecting Groundwater Quantity and Quality

Human population growth in some larger urban areas and increased irrigation of agricultural cropland have been creating challenges in protecting both groundwater quantity and quality. Increasing use of groundwater for municipal, industrial, and agricultural uses has in some places created substantial drops in local and regional groundwater levels. In some cases, surface waters such as springs and streams and wetlands dependent on groundwater discharge have had flows greatly reduced or have dried up completely. This is especially true in Brown, Dane, Waukesha, and Portage counties. In some cases, natural geologic conditions are combining with aquifer drawdowns of several hundred feet to introduce naturally occurring but formerly not problematic radium, arsenic, and other potentially harmful contaminants into drinking water. Proposed solutions to this situation are often tied to recent agreements regarding inter-basin transfer of water.

This presents an opportunity to promote water conservation and other policies that can help reduce the negative impacts to groundwater and groundwater-dependent natural communities, including the following:

- Documenting the impacts of high capacity wells on surface waters, aquatic life, and groundwater level sustainability. In addition, the proliferation of high capacity wells creates a need to continue to monitor overall groundwater and surface water consumptive uses. Special attention should be paid to areas with the most permeable shallow groundwater zones that feature high quality streams or in areas selected by using criteria that may developed as a result of proposed research.
- Advocating better regulation of withdrawal of both surface and ground water to limit harm to water-dependent natural resources where negative impacts that cannot be adequately addressed are demonstrated.

- Improving the current Groundwater Protection Law (WGCC 2009) using data from studies undertaken by the Wisconsin DNR, state universities, and agencies such as the Wisconsin Geological and Natural History Survey to guide those advocating the strengthening of existing state statutes.
- Regulating water withdrawals under terms of the Great Lakes Compact and Wisconsin statutes that implement the compact. Persons who withdraw surface water or groundwater from within the Great Lakes Basin at a rate that averages at least 100,000 gallons per day over any 30-day period will be required to obtain from Wisconsin DNR either an individual permit or coverage under a general permit. The permitting process in concert with other aspects of the compact, including requirements pertaining to water use registration and reporting, water conservation and efficiency, and water supply service area planning, will help to ensure that large water withdrawals do not result in significant adverse environmental impacts.
- The effects of laws implemented in the late 1990s allowing rural development and the placement of septic systems in areas with a high susceptibility to groundwater contamination need to be monitored, documented, and evaluated. More research is needed to monitor adverse impacts to wetlands, lakes, and groundwater from these septic systems. Regulatory or other measures should be advocated to eliminate these impacts where they are found to occur, and means to prevent them in other areas in the future should be devised.

Planning Opportunities for Aquatic Resource Protection

Improperly planned land use changes have created a wide range of ecological as well as societal problems in the past. There are many opportunities to limit the negative impacts of future land use changes. Continued land development requires more comprehensive and effective local and regional land use planning. Careful land use planning can prevent the loss of riparian habitat, degradation of water quality, and loss of fish and wildlife habitat associated with shoreline modification. Minimizing impermeable surfaces can increase groundwater infiltration and recharge groundwater levels as well as reduce excessive storm water runoff.

Because lake and river protection is vital to ***ecosystem health*** and local as well as statewide economic vitality, assistance of various kinds is available to local watershed protection advocates. Information on various assistance programs (including dam modification or removal; river, lake, and watershed planning; and nonpoint source pollution control) is available from the Wisconsin DNR's water program (WDNR 2014a, 2014d, and 2015a). These programs represent funding opportunities for accomplishing aquatic ecosystem management goals.

Opportunities for multi-agency or cross-jurisdictional cooperative planning to improve water resources include the following:

- Implementation of land use plans developed under (or previous to) Wisconsin's "Smart Growth" law provides an opportunity for improving land use to enhance and protect land and water. Local communities can be encouraged to develop or improve land use plans that have a significant focus on maintaining or improving water quality. Refining county agricultural shoreland management ordinances and purchasing conservation easements would help improve water quality and riparian habitat.
- When Wisconsin DNR Fisheries Management plans for the watersheds across the state are implemented and also when they are updated, the maintenance and improvement of overall biotic diversity should be considered. This will require the continued consideration of the needs of nongame as well as game species across a broad spectrum of taxa and aquatic habitats. Review proposals to introduce nonnative sport fish to those waters that are currently occupied by sensitive native species and have no nonnative species present.
- Management plans need to address an increase in fishing pressure along with advances in fishing equipment technologies that pose threats to maintaining quality fisheries on many lakes. Additional survey data to assess fish populations and habitat conditions are needed on a timely basis.
- Partnerships with institutions such as the University of Wisconsin-Extension, Natural Resources Conservation Service, county land and water conservation districts, and lake districts should be established to evaluate stakeholder needs and facilitate achievement of collective goals to protect rivers and streams. It may also help to maintain partnerships with other organizations capable of enhancing state protection capabilities, such as The Nature Conservancy, Northeast Wisconsin Land Trust, Ducks Unlimited, Pike Masters, Walleyes Forever, the U.S. Fish and Wildlife Service, U.S. Forest Service, tribal governments, city and county park systems, county forests, and other local units of government as well as local sport and recreation groups and private landowners. However, it is important to be aware of the sometimes single-purpose views of some organizations and to convey to them the broad and long-term benefits to be derived from adopting more holistic points of view.
- Cooperative agreements with private landowners should be developed for stewardship on private lands affecting important aquatic resources. Riparian lands should be the initial focus for these stewardship plans. Landowner objectives are key considerations when developing such plans and agreements.
- Lake water quality and habitat should be protected by adopting lake classification systems and enact changes to shoreland zoning ordinances. Increased development around small waterbodies and lake-associated wetland complexes

can result in the loss of habitat value for many wildlife species. Kettle lakes of the St. Croix Basin, lakes of northern Oconto County, and other lakes across the state are vulnerable to development because they are within easy commuting distances of the expanding Minneapolis-St. Paul, Green Bay, Wausau, and Eau Claire population centers.

- Floodplain protection can protect habitat, including wetlands, shorelines, and littoral zones, and help prevent flood damage. Working with local units of government and river or lake protection groups to further protect shorelands and control shoreline development can have multiple ecological and societal benefits.
- Strategies should be developed in land use plans to buffer the effects of nonpoint source pollution adjacent to critical or high quality aquatic habitat. While much progress has been made in addressing nonpoint source pollution, water assessments have documented the need for additional improvements (see Appendix A, "Watershed Water Quality Summary," in each ecological landscape chapter).
- Work with the Natural Resources Conservation Service and partner groups to permanently convert cropland to perennial cover, especially on slopes with erodible soils. Depending upon the agricultural economy and the status of state and federal programs, other opportunities may exist to help control agricultural nonpoint pollutant loading to surface waters.
- The addition of impermeable surfaces in urban and suburban development should be minimized wherever possible. Impermeable surfaces increase storm water volume and hence local flooding as well as carry excessive pollutant concentrations to surface waters. These hard surfaces also restrict groundwater recharge, which has become a groundwater supply and contamination factor in northeastern and southeastern Wisconsin.
- There are many opportunities to improve water quality through implementation of forestry and other best management practices (BMPs), including buffer strips, for control of nonpoint source urban, suburban, forestry-related, and agricultural pollutants. BMPs to maintain water quality merit support and promotion. For example, following well-managed construction site BMPs can decrease erosion by up to 80%. Sloping, erodible roadsides would benefit from additional nonpoint source pollution control measures as part of transportation BMPs. While BMPs are designed to protect water quality, there is a need for an assessment of the potential for BMPs to also contribute to better habitat protection.
- City planners should be encouraged to "build up" urban areas in already-developed sites in lieu of "building out" to new areas on a city's periphery.
- Wisconsin's storm water management requirements (NR 216, Wis. Adm. Code) as well as voluntary measures present an opportunity to improve water quality with storm water detention and infiltration sites. This requires effective storm water minimization and infiltration practices to limit effects on groundwater quality and aquifer storage.
- Municipal water system managers should be encouraged to reduce water losses in their distribution systems and expand water conservation measures by their customers.
- Municipalities should be encouraged to adopt comprehensive wellhead protection plans (as part of their overall land use plans) to both maintain infiltration of precipitation to aquifers and to minimize the potential for groundwater contamination.
- Public education efforts can be continued regarding regulations for permitting of pond construction adjacent to or connecting with navigable waters.
- Public education and regulation are needed to prevent damage to streams, lakeshores, and wetlands from motorized and even some nonmotorized recreation. Inappropriate mechanized recreation causes damage to aquatic vegetation and other habitats, introduction or resuspension of sediments, streambank erosion, and destruction or disturbance of fish spawning and wildlife nesting or resting sites.

Ecological Opportunities by Ecological Landscape

There are opportunities for preserving and managing aquatic communities throughout the state and in all ecological landscapes. For details, see "Statewide Ecological Opportunities for Aquatic Communities" above and the "Management Opportunities for Important Ecological Features" section in the individual ecological landscape chapters (Chapters 8-23). It may also be helpful to review the "Summary of Ecological Features and Management Opportunities at the Ecological Landscape Scale" section in Chapter 6 and the table in Appendix E, "Opportunities for Sustaining Natural Communities in Each Ecological Landscape," in Part 3 of the book, "Supporting Materials."

New Findings, Opportunities, and Conservation Needs

Recent and ongoing research and planning activities point to emerging or evolving opportunities to manage and protect aquatic resources. A proactive approach in dealing with these issues can help prevent unwanted water resource degradation and high costs of future cleanup.

- Ephemeral ponds are receiving attention from Wisconsin DNR inventory staff and some land managers. Some management guidelines are available now, and these will be refined as more information becomes available.

- The Lake Superior National Estuarine Research Reserve has been established in the St. Louis River Estuary in Douglas County by the National Oceanic and Atmospheric Administration, the University of Wisconsin Extension, the Wisconsin DNR, and other partners.
- Research information is now available to better support legal protection for springs. Spring protection in the southern half of Wisconsin may be especially important in light of the high level of agricultural, residential, industrial, and other activities on the landscape that can impact spring recharge and discharge areas. Springs are important ecological and cultural features no matter where they occur, and they warrant strong protection.
- The Peshtigo River State Forest was established in 2001, with final land acquisition occurring in 2004. This state property protects approximately six free-flowing miles of this important aquatic resource as well as 64 miles of Peshtigo River flowages and other streams.
- Fish ladder and ***fishway*** designs are improving and appear to be a feasible means of allowing a range of fish species to move around dams on some of Wisconsin's major rivers.
- Lake shores and river corridors continue to be highly valued sites for housing and other developments, leading to habitat loss, potential water quality problems, and the need for continued local land use planning.
- Ongoing research has consistently demonstrated the need for better land use planning and management to help protect and improve water quality in all types of settings—including residential lake developments, rural subdivisions, and agricultural areas.
- The continuing trend toward the expansion of irrigated cropland and increased demand for municipal groundwater pose risks to ground and surface water resources.
- Large livestock operations are increasing in numbers and are being sited in widely distributed locations. These create waste management problems and could impact groundwater as well as nearby rivers and streams.

Scientific names of species mentioned in the aquatic communities assessment.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Bighead carp	*Hypophthalmichthys nobilis*
Blackfin cisco	*Coregonus nigripinnis*
Blanding's turtle	*Emydoidea blandingii*
Blue-joint grass	*Calamagrostis canadensis*
Bullhead (sheepnose)	*Plethobasus cyphyus*
Brook trout	*Salvelinus fontinalis*
Bulrushes	*Scirpus* spp.
Cat-tails	*Typha* spp.
Chinook salmon	*Oncorhynchus tshawytscha*
Common carp	*Cyprinus carpio*
Common reed	*Phragmites australis*
Common Tern[a]	*Sterna hirundo*
Coontail	*Ceratophyllum* spp.
Creek chubsucker	*Erimyzon oblongus*
Curly-leafed pondweed	*Potamogeton crispus*
Deepwater cisco	*Coregonus johannae*
Freshwater drum	*Aplodinotus grunniens*
Dwarf lake iris	*Iris lacustris*
Eurasian water-milfoil	*Myriophyllum spicatum*
Fairy shrimp	Family Chirocephalidae
False hop sedge	*Carex lupuliformis*
Fat pocketbook	*Proptera capax*
Floating manna grass	*Glyceria septentrionalis*
Flowering rush	Butomus umbellatus
Fowl manna grass	*Glyceria striata*
Ghost shiner	*Notropis buchanani*
Hall's bulrush	*Schoeoplactus hallii*
Higgins' eye	*Lampsilis higginsii*
Hine's emerald dragonfly	*Somatochlora hineana*
Ironcolor shiner	*Notropis chalybaeus*
Kokanee salmon	*Oncorhynchus nerka*
Lake Huron locust	*Trimerotropis huroniana*
Lake sturgeon	*Acipenser fulvescens*
Lake trout	*Salvelinus namaycush*
Marsh mermaid-weed	*Proserpinaca palustris*
Milfoil	*Myriophyllum* spp.
Muskellunge	*Esox masquinongy*
Narrow-leaved cat-tail	Typha angustifolia
Orange jewelweed	*Impatiens capensis*
Osprey	*Pandion haliaetus*
Paddlefish	*Polydon spathula*
Pallid shiner	*Notropis amnis*
Piping Plover	*Charadrius melodus*
Pondweeds	*Potamogeton* spp., *Stuckenia* spp.
Purple loosestrife	*Lythrum salicaria*
Pygmy whitefish	*Prosopium coulteri*
Quagga mussel	*Dreissena bugensis*
Rainbow smelt	*Osmerus mordax*
Red shiner	*Cyprinella lutrensis*
Reeds	*Calamagrostis* spp, *Sparganium* spp., *Phragmites australis americanus*, and *Cinna latifolia*
Round goby	*Neogobius melanostomus*
Ruffe	*Gymnocephalus cernuus*
Rusty crayfish	*Orconectes rusticus*

Continued on next page

Scientific names of species, continued.

Common name	Scientific name
Scaleshell mussel	*Leptodea leptodon*
Sea lamprey	*Petromyzon marinus*
Sedges	*Carex* spp.
Shortnose cisco	*Coregonus reighardi*
Silver carp	*Hypophthalmichthys molitrix*
Slender madtom	*Noturus exilis*
Smartweeds	*Polygonum* spp.
Snapping turtle	*Chelydra serpentina*
Snuffbox mussel	*Epioblasma triquetra*
Solitary Sandpiper	*Tringa solitaria*
Spatterdock	*Nuphar* spp.
Spectacle case mussel	*Cumberlandia monodonta*
Spiny water flea	*Bythotrephes cederstroemi*
Spotted water-hemlock	*Cicuta maculata*
Striped shiner	*Luxilus* (formerly *Notropis*) *chrysocephalus*
Threespine stickleback	*Gasterosteus aculeatus*
Tubenose goby	*Proterorhinus marmoratus*
Walleye	*Sander vitreus*
Water-parsnip	*Sium suave*
Waterweed	*Elodea* spp.
Western mosquitofish	*Gambusia affinis*
White grass	*Leersia virginica*
White perch	*Morone americana*
Wild rice	*Zizania* spp.
Winged mapleleaf	*Quadrula fragosa*
Wood frog	*Rana sylvatica*
Wood turtle	*Glyptemys insculpta*
Yellow water crowfoot	*Ranunculus flabellaris*
Zebra mussel	*Dreissena polymorpha*

[a]The common names of birds are capitalized in accordance with the checklist of the American Ornithologist Union.

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Statewide Socioeconomic Assessments

As noted in the Introduction, one of the goals of this publication is to assess the ecological resources and socioeconomic conditions for the 16 ecological landscapes in the state. Inherent in this goal is the need to provide a broader ecological and socioeconomic context for the individual ecological landscapes. In attempting to provide that context, this section describes (1) the history of human settlement and resource use in the land that would become Wisconsin, from the earliest known human occupation until World War II, (2) more recent resource characterization and use in the state, and (3) a socioeconomic overview of present-day Wisconsin.

History of Human Settlement and Resource Use

This section describes historical settlement patterns in Wisconsin from the earliest known human occupation to the period of broadscale Euro-American settlement in the early to mid-19th century; it also describes how natural resources were used by the region's earliest inhabitants, its 19th-century Euro-American settlers, and its early 20th-century population. Over the last two centuries as the human population of Wisconsin has dramatically increased, lessons have been learned and policies created to help manage the state's resources. Some of these policy decisions will be discussed.

Access to natural resources had a direct influence on American Indian and Euro-American settlement, just as settlement had a direct effect on the natural resources of the state. Over time, the early inhabitants of the region switched from a primarily nomadic lifestyle to a more sedentary one, especially as fertile lands were successfully converted to agricultural fields. Mining was also important to the early inhabitants of Wisconsin for thousands of years, beginning as early as 7,000 years ago. Mining efforts were significant and contributed to the supply of available trade goods. American Indian and, later, Euro-American, settlement patterns were influenced by the location of mineral deposits, fertile land, and mature timber. The extensive network of waterways in and around the region expedited the transportation of resources and facilitated trade. By the mid-19th century, railroad construction had begun to connect major population centers, mines, and lumber mills. As technology advanced and transportation improved, the connection between settlement and resource use became less of an issue.

American Indian Settlement

A wide range of evidence points to humans having arrived in Wisconsin from a generally southern direction as the glaciers were receding, approximately 11,300 years ago (Mason 1997). The first humans to arrive in the state are associated with the group of cultures known as Paleo-Indians, a term that refers to the group whose remains clearly indicate the earliest human inhabitants of America (Mason 1997). They arrived in America via the Bering Land Bridge during the Pleistocene glaciation, sometime after 16,500 years ago, and spread relatively rapidly across the entire continent (Goebel et al. 2008). Paleo-Indians are associated with distinctive fluted projectile points generally referred to as "Folsom" and "Clovis" points. Folsom points, although famously first discovered associated with the bones of an extinct species of bison near Folsom, New Mexico, in 1926, are somewhat younger than Clovis points, which were discovered on the Great Plains associated with butchered mammoth remains. Both Clovis and Folsom points have been discovered in Wisconsin, with Clovis points being somewhat more common (Mason 1997). These first humans were sparsely populated, widely mobile hunting and gathering societies, exploiting lands never previously occupied by humans (Mason 1997). Among other things, they hunted and scavenged Pleistocene megafauna such as mammoth and mastodon. The Paleo-Indian Tradition lasted until approximately 10,000 years ago in southern Wisconsin but persisted later in northern Wisconsin.

The Archaic Tradition is largely a continuation of the Paleo-Indian Tradition. However, with the receding glaciers, larger big game species that were adapted to colder climatic conditions moved northward toward the glaciers or went extinct. According to Stoltman (1997), one way to distinguish the Archaic Tradition from its Paleo-Indian predecessors is that Archaic peoples were hunting and gathering the modern suite of plant and animal species. The most famous innovation of the Archaic Tradition that occurred approximately 7,000 years ago is the mining and working of native copper into a wide variety of tools and, much less often, ornamentation (Stoltman 1997). The Archaic Tradition is generally considered to have endured from approximately 10,000 to 9,000 years ago until between 2,500 and 2,300 years ago in southern Wisconsin, while it began somewhat later in northern Wisconsin (from approximately 8,500 to 7,500 years ago) and lasted until the early centuries of the first millennium AD.

The Woodland Tradition is generally described as ushering in three major cultural innovations: agriculture, pottery, and the construction of burial mounds (Stevenson et al. 1997, Stoltman 1997). As with earlier traditions, these innovations occurred at different places, at different times, although they generally occurred first in southern Wisconsin, and were carried north. All of these innovations indicate a less mobile society, with greater association with particular places on the landscape (Stevenson et al. 1997). While native copper was still used by Woodland peoples, it was much more commonly used as ornamentation, and few copper tools from this tradition are known (Stoltman 1997). Toward the end of the Woodland Tradition, the use of bow and arrow became more widespread, as did the cultivation of corn. The Effigy Mound culture emerged, characterized by the construction of numerous mounds, many in the shapes of animals as well as a few shaped like human beings. The Effigy Mound culture was found mostly in the southern half of the state. The Woodland Tradition persisted in the south until approximately 700 years ago but lasted longer in the north, into the historical period.

During the Late Woodland period, between approximately 1,200 or 1,000 years ago, an influx of technology and culture associated with the city-state of Cahokia in the American Bottom region of southern Illinois began to become evident in Wisconsin. Cahokia, an enormous city and cultural center along the Mississippi River, had influence across a large area in the central United States, beginning approximately 1,200 years ago, and persisted until approximately 700 years ago. It was the center of the "Middle Mississippian" or "Mississippian" culture, which attained a higher degree of complexity to the political, social, and religious systems than had ever occurred in this region (Griffin 1985). They created large, earthen platform mounds upon which structures were built to house the elite or religious leaders or for ceremonial use. Wisconsin is considered the "northern hinterland" of Mississippian culture, and it is unclear whether immigrants in numbers ever arrived or whether the people of Wisconsin adopted or emulated customs from the south through trade and other interaction (Green 1997). Distinctive forms of shell-tempered pottery with origins to the south have been found in association with Mississippian sites in Wisconsin, as well as copies of those same forms of pottery made with local materials. Aztalan, the most famous archaeological site in Wisconsin, has clear Middle Mississippian influence, including platform mounds, distinctive pottery, and a stockade that surrounded the central plaza. It was occupied between approximately 1,200 years ago until 800 years ago. During the Late Woodland period, the Woodland Tradition persisted in parallel to the Mississippian Tradition, with villages in Wisconsin exhibiting the attributes of one or the other tradition.

By approximately 800 years ago, a "new" culture, known as the Oneota Tradition, began to take hold in Wisconsin as well as in much of the Midwest. The use of crushed shell temper in their pottery was common throughout southern Wisconsin, although the forms were different from the Mississippian pottery. They were likely more sedentary than their predecessors, with their typical settlement described as a "village farming community" and generally situated close to larger lakes, rivers, or marshes with adjacent soils suitable for agriculture (Overstreet 1997). While Oneota peoples have traditionally been considered to be the forebearers of the Ho-Chunk in Wisconsin, there are gaps in the archaeological record that make this difficult to link empirically, but this connection is considered to be likely (Mason 1988).

These early inhabitants of the region surely affected the native vegetation in significant ways, including using fire for driving game and clearing land for agriculture (Gartner 1997). Landscapes such as savannas, barrens, prairies, fens, shrublands, sedge meadows, and pine forests are thought to have been maintained, and may even have been established, by the high frequency of human-caused fire (Curtis 1971).

By the 1630s, three tribes were residing in Wisconsin. The Ho-Chunk (Winnebago) lived between Green Bay and Lake Winnebago. The Menominee lived along the Menominee River (west of Green Bay). The Santee Dakota inhabited northwest Wisconsin. During this time, tribal wars in what is now the eastern U.S. caused many tribes to relocate west. Within the next 20 years, the Fox, Sauk, Huron, Miami, Illinois, Ottawa, Ojibwe (Chippewa), Kickapoo, Mascouten, and Potawatomi Indian tribes had established themselves in Wisconsin (Curtis 1971).

French explorer Jean Nicolet crossed Lake Michigan from Canada in 1634, landing near present-day Green Bay (WHS 2012). Twenty years later, the first French fur traders arrived in Wisconsin, followed by many other traders, explorers, and missionaries. By the end of the 17th century, the fur trade was firmly established in Wisconsin. The French formed alliances with the Great Lakes tribes, purchasing furs and introducing them to European trade goods such as guns, ammunition, metal knives, kettles, and blankets. The French controlled the fur trade in the Great Lakes region until after the French and Indian War (1755–1763), when control of the Great Lakes region transferred from the French to the British. In 1784 the United States and Great Britain signed a treaty allowing British and Canadian fur traders to continue working in the Great Lakes region, and the British continued to control the fur trade until 1815 (MPM 2012b). By 1820 the overexploitation of northern Wisconsin furbearers caused the fur trade to move north into Canada.

Under the Indian Removal Act of 1830, signed into law by President Andrew Jackson, tribes living east of the Mississippi River were removed from their lands and relocated west of the Mississippi (Satz 1991). Through a series of removal treaties, the U.S. Government acquired lands from the Wisconsin tribes. In return for ceding their lands to the United States, the Wisconsin tribes received cash payments and goods such as utensils, guns, ammunition, beaver traps, and blankets.

The treaties were sometimes negotiated by tribal members who didn't have the authority to speak for the tribe or sign treaties on the tribe's behalf (the cause of the Black Hawk War was a disputed treaty). There were also problems with interpreters and what the tribal leaders understood they were agreeing to (Satz 1991). Another problem was that the tribes traditionally made verbal agreements, and with the negotiations, things were discussed that didn't always end up in the treaties. The goods they received were often of poor quality (thin blankets, cheap pots, etc.), and the money was often paid directly to the traders with whom the Indians traded and to whom the Indians were in debt. These debts to traders were also used to force the tribes to negotiate treaties. The Ho-Chunk, Sauk, Fox, Potawatomi, and Ottawa gave up their lands and left the region, although some Ho-Chunk and Potawatomi refused to leave or later returned (MPM 2012a).

There are six major tribes in Wisconsin today: the Ho-Chunk (Winnebago), Menominee, Ojibwe (Chippewa), Oneida, Potawatomi, and Stockbridge-Munsee (Mohican). Together they own approximately 447,000 acres of reservation land throughout Wisconsin. The Menominee hold the majority of this land, with 237,841 acres (WLRB 2011).

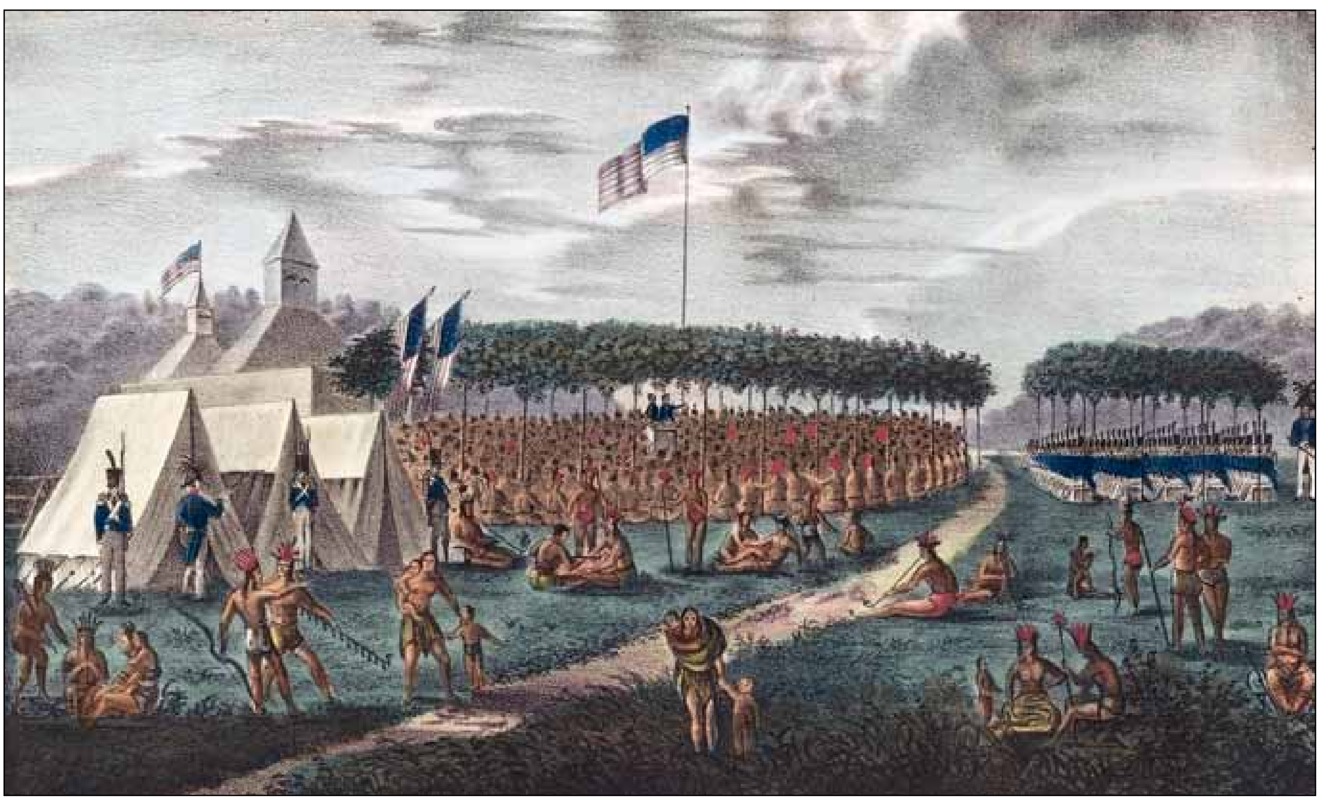
Many tribal members still engage in traditional practices such as wild rice harvesting and subsistence fishing, hunting, and gathering. Each tribe owns and operates at least one casino. Revenue from the casinos has provided employment, improved healthcare, educational, better housing, etc., to tribal members as well as provided input to local economies in Wisconsin. The history, settlement, and resource use of the six tribes follows.

Ho-Chunk (Winnebago)

While there are gaps in the archaeological record, it is considered likely that the Ho-Chunk are the descendants of the Oneota Culture in Wisconsin (Mason 1988). Historical records indicate that the Ho-Chunk had settlements near Green Bay, the upper Fox River, and Lake Winnebago. The influx of other tribes such as the Potawatomi from the north helped to push the Ho-Chunk westward. The move westward was also influenced by the Ho-Chunk owning horses, which allowed them to hunt the better hunting grounds in western Wisconsin, and because the Mississippi River offered expanded trade opportunities with the Euro-Americans. By the 18th century, the Ho-Chunk had reached the Mississippi River and claimed lands from the Mississippi north to the Black River and south to the Wisconsin River. They were known to have crossed the Mississippi to hunt bison on the plains. They maintained villages in eastern Wisconsin until the 1800s, but eventually these claims were abandoned.

A treaty of peace and friendship was signed between the Ho-Chunk and the U.S. Government in 1816, the first of many treaties signed between the tribe and the United States (Ho-Chunk Nation 2012). In 1825 a treaty was signed at Prairie du Chien between the U.S. Government and the Wisconsin tribes, which established tribal boundaries for the Ho-Chunk, Ojibwe, Potawatomi, and Menominee tribes as well as other tribes then living in the region (Sioux, Sac and Fox, Ottawa, and Ioway tribes). The terms of the treaty were ignored by Euro-American settlers, who moved into Ho-Chunk lands, attracted by its rich farmland and the lead mines that had been mined by the Ho-Chunk and other tribes for hundreds of years.

With the growing Euro-American population, the Ho-Chunk were removed from Wisconsin to northeastern Iowa, then, 10 years later, to the northern Minnesota territory (Ho-Chunk Nation 2012). In 1863 the Ho-Chunk were moved further west to a desolate reservation in South Dakota;



Lithograph by James Otto Lewis depicting 1825 treaty held at Prairie du Chien. Image courtesy of the Wisconsin Historical Society (Image ID 3142).

the following year, the tribe was allowed to exchange its reservation lands in South Dakota for a reservation in Nebraska. Throughout this series of removals, small groups of Ho-Chunk secretly remained in Wisconsin or returned to Wisconsin. Once it became clear that many Ho-Chunk were determined to stay in Wisconsin, the federal government finally relented and granted Ho-Chunk families 40-acre homesteads, encouraging them to farm and "assimilate" into the dominant American culture.

Because the Wisconsin Ho-Chunk didn't live on a reservation, they didn't have official status as a tribe with the U.S. Government (Ho-Chunk Nation 2012). In 1963 the tribe officially reorganized under the Indian Reorganization Act of 1934 and were recognized by the government as having tribal status. Although the Ho-Chunk Nation doesn't own a reservation, the tribe owns property throughout Wisconsin. Ho-Chunk enterprises include casinos, campgrounds, lodging and meeting facilities, gas stations, convenience stores, and a bottled water business (WSTRI 2010).

Menominee

The Menominee, whose name means "wild rice people," inhabited large areas of northeastern Wisconsin at the time of Euro-American contact. Even with the influx of other tribes, the homeland of the Menominee remained relatively stable over time, eventually centering on the lower Fox River (Mason 1988). They came to claim large sections of what had been Ho-Chunk (Winnebago) land as the Ho-Chunk were forced westward. In the 18th century, during the wars between the Santee Dakota and the Ojibwe, the Menominee also moved into areas in western Wisconsin and hunted and trapped the lands that neither tribe could claim and hold.

As with all of the Wisconsin tribes, they ceded large areas of land to the U.S. Government during the mid-1800s. In 1854 they signed a treaty that established a reservation of more than 250,000 acres, mostly in present-day Menominee County (MPM 2012c). In 1856 another treaty granted about 46,000 of Menominee land to the Stockbridge-Munsee bands of Mohicans.

In the late 1940s through the early 1960s, a policy called "termination" was promoted by some congressional leaders and Washington bureaucrats who sought to end federal supervision and trust responsibilities over tribes and reservations (MPM 2012c). The Menominee Nation was the first tribe to be affected by this policy and was singled out because the tribe had been economically successful with a lumber mill operation, and it was believed the tribe would be able to sustain itself after termination. In June 1954, President Eisenhower signed the Menominee Termination Act into law. The termination program phased out the existence of the Menominee Reservation and ended tribal sovereignty on April 30, 1961, when the reservation became a new Wisconsin county, Menominee County. Commonly held tribal property was transferred to a corporation called Menominee Enterprises, Inc. (MEI), through which each tribal member was a shareholder; however, the MEI board of directors was not composed of Menominee tribal members, and tribal shareholders had little control over MEI recommendations.

Gathering wild rice. Engraving by Seth Eastman. Image courtesy of the Wisconsin Historical Society (Image ID 9023).

The new Menominee County didn't have enough of a tax base to support county and local services, and by 1964 the tribe's assets had dwindled (MPM 2012c). The MEI put forward a plan to its shareholders that tribal land be sold as a way to raise money, and most shareholders voted for the plan. However, when MEI contracted with a private developer who intended to create a large lake and develop the property around the lake for sale to non-Indians, tribal members organized against the plan and created the Determination of Rights and Unity for Menominee Shareholders (DRUMS) organization. Over the next years, the DRUMS group protested against the lake development plan and also began putting up its own candidates up for election to the MEI board of directors. By 1972, DRUMS controlled the MEI board and were able to block the development project.

DRUMS also worked to reverse termination (MPM 2012c). Finding an ally in President Richard Nixon, who opposed termination, DRUMS successfully lobbied Congress for a law that would return federally recognized sovereignty to the Menominee Nation, restore federal services to the tribe, and restore tribal control over its members and property. On December 22, 1973, the president signed the Menominee Restoration Act, and in April 1975, Menominee County became federally recognized as the Menominee Indian Reservation. Today, the Menominee Reservation is comprised of 235,000 acres. Its business enterprises include a casino and resort, a gasoline station, and a sawmill operation (WSTRI 2010).

Ojibwe

The Ojibwe, also known as Chippewa, began as generally small bands of people with common language and culture living north of Lake Huron and extending west to lands north of Lake Superior (Mason 1988). They are known to have occupied a fishing village by the middle of the 17th century at Sault Ste. Marie (Hickerson 1970). The Ojibwe expanded westward along the south shore of Lake Superior into Wisconsin, establishing a settlement in Chequamegon by 1695 (Mason 1988). At first, the Ojibwe were in an alliance with the indigenous Santee Dakota, but this alliance deteriorated into raids and counter raids as time went on. The French attempted to broker peace between the two tribes, as it was in their best interests for peaceful trade to occur. By the beginning of the 18th century, this attempt at peace had all but failed. By 1766 the Ojibwe had reached the Mississippi River, and by the beginning of the 19th century, had all but pushed the Santee Dakota out of Wisconsin, with the Mississippi acting as the boundary between the two warring tribes.

The Ojibwe made two major land cession treaties with the U.S. Government: in 1837, when the they ceded lands in northern Wisconsin and eastern Minnesota, and in 1842, when they ceded their remaining lands in northern Wisconsin and Michigan's Upper Peninsula (Satz 1991). The Ojibwe believed that under the 1837 and 1842 treaties, they wouldn't be forced to leave the ***ceded territory*** unless they acted violently against white settlers. However, there were persistent rumors that the U.S. Government planned to force them to leave their homeland, and in late 1848, a group of Ojibwe Indians, including the chiefs of the Lake Superior bands, traveled to Washington, D.C., to present a petition to Congress requesting the establishment of a permanent home in Wisconsin. Ignoring their petition, on February 6, 1850, President Zachary Taylor signed an Executive Order revoking Ojibwe rights as set out by the treaties and ordering that all Chippewa remaining on ceded lands be removed to lands west of the Mississippi River.

In 1852 another Ojibwe delegation traveled to Washington with a petition to present their grievances (Satz 1991). They met with President Millard Fillmore, who rescinded the Removal Order and agreed to end all efforts to remove the Ojibwe from Wisconsin. In 1854 the U.S. Government negotiated another treaty with the Ojibwe, who refused to cede their remaining lands in Minnesota until they had been granted permanent reservations in Wisconsin. The 1854 treaty created four Ojibwe reservations at Bad River, Red Cliff, Lac du Flambeau, and Lac Courte Oreilles.

Today, the Bad River Reservation totals 125,655 acres, the Red Cliff Reservation totals 14,541 acres, the Lac du Flambeau Reservation totals 86,600 acres, and the Lac Courte Oreilles totals 76,465 acres, of which 10,500 acres are lakes (WSTRI 2010). Two additional Ojibwe reservations were created following the 1934 Indian Reorganization Act: the Mole Lake Reservation, which totals 4,900 acres, and the St. Croix Reservation, which totals 4,689 acres. Ojibewe business enterprises include casinos/resorts, restaurants, campgrounds, gas stations/convenience stores, commercial fishery/fish hatchery, marina, cranberry operation, construction, and custom wood furniture, among other business operations.

Oneida

The Oneida Nation, a subgroup of the Iroquois, originated in present-day New York (Oneida Nation 2012b). They were forced out of their homeland and relocated to Wisconsin by means of a treaty with the Menominee and Winnebago (Ho-Chunk) Indians. There were three waves of migration from New York to Wisconsin. The first was in 1822 when approximately 450 Oneidas settled in the Grand Chute and Kaukauna area. In 1823 another 200 Oneidas settled along the south edge of Duck Creek, just north of Green Bay. Reservation boundaries were established by an 1838 treaty between the Oneida and the U.S. Government. In 1841 an additional 40 Oneidas settled in the Chicago Corners area, just north of Freedom.

In 1887 Congress passed the Dawes Act, also known as the General Allotment Act, which mandated that tribal lands be surveyed and reservations be broken up into small allotments and parceled out to individual tribal members (Oneida Nation 2012a). It was thought that if individual Indians were allotted their own land to farm, they would assimilate into the mainstream culture. The Act required that federal government hold the lands in trust for the American Indian owners for a period of twenty-five years, after which individuals could sell or lease their land. "Surplus" lands (lands not allotted to tribal members) could be sold or leased by the federal government. For the Oneida, however, there was no surplus reservation land because, given the tribe's population and the size of the reservation, there was not enough land to provide the required allotment of 160 acres to each head of household, and smaller allotments were parceled out.

After the twenty-five year trust period ended, much of the land was purchased by non-Indians when individuals sold their land, lost it through tax foreclosures, or lost it through bank foreclosures when they borrowed money, using the land as collateral, and weren't able to repay the loan (Oneida Nation 2012a). The Oneida Reservation, established by the 1838 treaty, was originally 65,428 acres; by the 1920s, only a few thousand acres remained in ownership of Oneida tribal members. The original reservation boundaries still exist as set out in the 1838 treaty, even though the tribe no longer controls all of the land.

The federal allotment and assimilation policy was reversed in 1934 with the passage of the Indian Reorganization Act, which recognized tribal authority and allowed tribes to establish tribal governments (Oneida Nation 2012b). In 1936 the Oneida Nation adopted a constitution and elected a tribal governing body. The following year, the federal government purchased 1,270 acres of land within the reservation boundaries and placed it in trust for the Oneida Nation. Since then, the tribe has continued to purchase back its lands within the original reservation borders set in 1838 and has purchased many thousands of acres with casino revenues. As of 2010, the Oneida Reservation comprised 65,400 acres (WSTRI 2010). Business enterprises owned by the Oneida Nation include a casino and hotel, apple orchard, beef cattle operation, a real estate business, grocery store, convenience store, golf course, bank, and a construction business.

Potawatomi

The Potawatomi are closely related to the Ojibwe. Early historical records report the Potawatomi living in the Lower Peninsula of Michigan, with some living on the eastern shore of Lake Michigan (Quimby 1960). Sometime after Nicolet's voyage in 1634, the Potawatomi were pushed north, eventually finding refuge in Sault Ste. Marie (Mason 1988). By 1648 they had moved south through the Upper Peninsula of Michigan and settled the area around Green Bay (Clifton 1977). They built a stockaded village in the vicinity of what is now Manitowoc, along with some Hurons, Petuns, and Ottawas who had also been forced to flee raids from the Iroquois. In 1653 this combined group defeated the Iroquois, who had laid siege to the village. This village has not yet been discovered, but is of historical interest as the village was named "Mechingan" meaning "Great Lake" which led to the name of Lake Michigan (Mason 1988).

Their victory over the Iroquois led to new military and political power for the Potawatomi, who now controlled much of northeastern Wisconsin, which allowed them to move southward to claim lands more suitable for agriculture. By 1704 they had reclaimed some of their former lands in Michigan, spreading as far eastward as Detroit and controlling areas in Indiana and northern Illinois (Mason 1988). In the 18th century, the Potawatomi were fighting alongside the French, serving in the French and Indian War as well as in other skirmishes between the French and English.

During the 19th century, the Potawatomi ceded much of their land to the U.S. Government. An 1833 treaty required the Potawatomi to leave Wisconsin by 1838, and most of the Potawatomi population was forced to move westward and eventually were relocated to a reservation in Kansas (Forest County Potawatomi 2012). A remnant population of Potawatomi remained in the state, in present-day Forest County. For many years, only the Kansas Potawatomi were paid the annuities for land ceded to the United States, but in 1913 the federal government paid the Forest County Patowatomi treaty money long overdue for ceded lands, which allowed the tribe to purchase land in Forest County for a reservation (MPM 2012d). Under the Indian Reorganization Act of 1934, the Potawatomi were reorganized into the Forest County Potawatomi Community, but it wasn't until 1988 that the Potawatomi lands in Forest County were granted "reservation" status. Today, the Potawatomi Reservation comprises 12,000 acres (WSTRI 2010). The Forest County Potawatomi Community owns and operates two casinos, a newspaper, a hotel and conference center, a deer farm, a gas station/convenience store, and a real estate/development business.

Stockbridge-Munsee (Mohican)

The Stockbridge-Munsee descend from Algonquin-speaking peoples of the northeastern United States, the Mohicans and the Munsee Delawares (MNSMB 2012). Tensions between the Mohicans, other American Indian tribes, and Euro-Americans caused the relocation of the Stockbridge and Munsee Bands to present-day Wisconsin where land was negotiated with the help of missionaries, the State of New York, commissioners from the War Department, and the Menominee and Winnebago Indians already established in Wisconsin. The Stockbridge Band was the first to move to Wisconsin. In 1822 they built a village near what is now Kaukauna, and over the next years, more Stockbridge relocated to Wisconsin. By 1831 a band of Munsee Delaware had joined the Stockbridge in Wisconsin, and the community became known as the Stockbridge-Munsee. In 1834 the Stockbridge and Munsee Bands relocated to the east shore of Lake Winnebago. After another two decades of treaty negotiations, the Stockbridge and Munsee Bands made their final move to Shawano County in 1856 onto land obtained from the Menominee Indians.

The passage of the 1887 Dawes Act (General Allotment Act) was the first of a series of congressional acts that broke up Stockbridge-Munsee lands, concluding in 1910 with an act that completed the division and allotment of Stockbridge-Munsee lands in Shawano County, dissolved the tribal government, and ended its status as a federally recognized tribe (MNSMB 2012). Most of the land was lost when allotments were sold to non-Indians or lumber companies or when individuals couldn't pay the property taxes or lost their land through bank foreclosures.

Following the Indian Reorganization Act of 1934, which allowed for the reestablishment of tribal governments and reservations, the Stockbridge-Munsee reorganized, adopted a new constitution, and, with federal funds, began buying back some of the land within their old reservation boundaries, regaining about 15,000 acres (MNSMB 2012). However, at that time only about 2,500 acres of the 15,000 acres were placed in federal trust as reservation lands for the tribe, now officially recognized as the Stockbridge-Munsee Band of Mohican Indians. It wasn't until 1972 that the federal government placed the remaining 13,000 acres of land in trust for the tribe. Today, the Stockbridge-Munsee Reservation totals 22,139 acres (WSTRI 2010); the tribe's business enterprises include a casino, golf course, supper club, convenience store, and RV campground.

Euro-American Settlement and Early Agriculture

True Euro-American settlement was not present in Wisconsin until after the Black Hawk War ended in 1832 and after the first treaties were signed between the federal government and American Indian tribes of the region. As the ceded lands opened up, land-hungry Euro-American settlers moved into the region, taking up land for agriculture, mining, and timber extraction.

Southern Wisconsin

Broadscale Euro-American settlement first occurred in the southern portion of the state in the 1830s. The fertile lands in the southern part of the state were surveyed, and farmers were then able to lay claim to the land (Austin 1964). The first settlements began in the former lead-mining district in the southwest and in the mixed forest and prairie areas of the southeast (Ostergren 1997). Farmers were attracted to the oak openings of south central and southwestern Wisconsin. The presence of oaks suggested productive soil conditions, and the openness eased the clearing of land (Austin 1964). In southwestern Wisconsin, productive agriculture was restricted to valley bottoms and ridge tops, resulting in a scattered settlement pattern.

Settlers were attracted to southeastern Wisconsin for several reasons. The inland prairie landscape was easy to clear, and the soils were more fertile than the rest of the state as a whole. The area along the Lake Michigan shore was maple forest, indicative of productive soils. The proximity to Lake Michigan provided the opportunity for lakeshore markets. Southeastern Wisconsin was a main stopping point for German settlers. In 1850 the German population of Wisconsin was over 38,000 people. More than half of the German settlers lived in Ozaukee, Milwaukee, and Washington counties (Austin 1964).

By 1850 there were more than 305,000 Euro-American settlers in Wisconsin. Nearly two-thirds of that population were American-born, primarily from New York and the New England states (Austin 1964). Wisconsin was a major producer of wheat during the 1840s and 1850s (Ostergren 1997), a crop brought to the state from the east coast. Since the 1880s, dairying has been the most profitable form of agriculture for Wisconsin farmers (Austin 1964).

A group of men and boys threshing, using a steam tractor for a belt-driven threshing machine (about 1900); on the left, two horses pull a wagon with large barrels. Photograph courtesy of the Wisconsin Historical Society (Image ID 84219).

Northern Wisconsin

Between 1850 and 1920, much of the work force in northern Wisconsin was employed in timber and timber-related occupations. By the end of the 19th century, a board of immigration was created by the state legislature to promote agricultural settlement in northern Wisconsin, with unrealistic promotion of the region's agricultural potential (Ostergren 1997). Slash and brush that remained after timber harvest was usually burned to clear the land, and explosives were sometimes used to dislodge stumps. In addition, glacial deposits of rocks and boulders had to be removed before the land could be plowed. The nutrient-poor, sandy soil and short growing season were more hospitable for grass and clover than traditional row crops. These plants could be sown among the tree stumps and survived in nutrient-deficient soils. Planting grass and clover also helped the timber industry because the pastures and hay were a food source for the horses used in the timber camps.

The cold northern climate was viewed as being advantageous for sheep farmers because it seemed to promote a thicker coat of wool. The cold also seemed to discourage parasites and disease. Peas, oats, and roots would grow in the region and were considered exceptional feed for horses, sheep, and dairy cows. The climate and crops that could be grown here were also advertised as being ideal for swine breeding. Other options for farmers included raising eggs and poultry and growing potatoes, which seemed to do quite well in some areas with fertile, sandy loam soil.

Northern farms were generally isolated from one another and were sometimes owned by settlers with little or no farming experience. When hard economic times came with the Great Depression, farmers were often unable to pay their taxes, and lands were abandoned or the settlers went on public relief, directly affecting the regional economy. The State and County Forest systems were created when the government took possession of tax delinquent lands (Foust et al. 1983). By the 1920s, land clearing for agricultural settlement had all but stopped. In 1927 the ***Forest Crop Law*** was created; under this law, land could be reforested and no tax would have to be paid until the timber was harvested. Settlers who chose this option replanted their land with jack pine, red pine, and white spruce. In 1929 the legislature sanctioned county-wide zoning that would encourage settlers to move closer together as a way of invigorating economic growth in logged-over areas (Ostergren 1997).

Early Mining

Euro-American settlers began mining in southwestern Wisconsin during the 1820s (Austin 1964). This lead-mining region included Iowa, Grant, and Lafayette counties and western portions of Dane and Green counties. The first people who began this lead mining effort were Euro-Americans from the southern states. Within the next decade, British immigrants arrived, followed in turn by the Germans and Scandinavians. Shanty towns and permanent mining settlements were quickly established. In the early mining days, lead was hauled to Galena, Illinois, and shipped down the Mississippi River. By the late 1830s, lead was carried on wagons to Milwaukee where it was then shipped east on the Great Lakes. The lead mining era peaked in the 1840s with annual production at approximately 18 million pounds.

Copper and iron ore mining attracted people to the northern third of Wisconsin in the mid-1800s (Mahaffey and Bassuk 1978). Cornish and Finnish immigrants were recruited for their expertise in mining. Following the Cornish and Finns, other Scandinavian, Italian, Slavic, and German immigrants began to arrive. In northern Wisconsin, iron ore mining occurred around Florence and Hurley. Mining operations in Florence could not compete with those in neighboring areas and ended by 1931. Deep-shaft iron ore mining near Hurley in what is known as the Gogebic Range has been continuous since its inception in the 1880s (WSPB 1939).

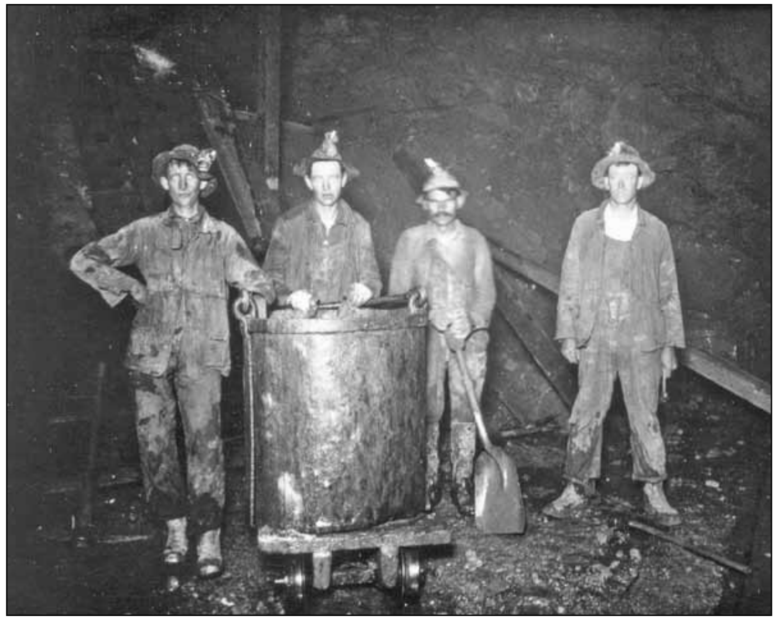
Early Transportation and Access

Early settlements in Wisconsin were generally found along main water routes. American Indians traveled over water by canoe, and many early Euro-Americans arrived by boat. Access to the resources of the region was gained by navigating the network of lakes and rivers. Talk of railroads began in the mid-1830s as a way to expedite the movement of lead from the mining district in southwestern Wisconsin. Actual construction of railroads did not begin until 1850. The first tracks were laid in the southeastern part of the state, connecting Milwaukee and Waukesha by a company uniquely titled the Milwaukee and Waukesha Railroad Company (Austin 1964). By 1853 the line had been expanded to connect to Eagle then Milton then Janesville. The line would continue on to reach the Wisconsin River and then the Mississippi River at Prairie du Chien.

In 1851 a line running north and south was built. Named the Rock River Valley Union Railroad Company (previously called the Madison and Beloit Railroad Company), the line ran from Janesville north to Fond du Lac and Oshkosh and south to Chicago (Austin 1964). Many other railroads were established during this time with the help of land grants from the federal government. However, during the economic panic of 1857, all railroads in Wisconsin went bankrupt (Austin 1964). Farmers who had invested in railroad stock began to lose their farms to eastern banks that held their mortgages. The farmers resisted, causing a series of legislative maneuvers that ultimately called for canceling the mortgages in lieu of some fairly minor penalty, such as repayment of a portion of the principal. In 1860 there were 891 miles of railroads throughout the state. Railroad building began again after the Civil War and increased dramatically.

In response to the timber harvest in northern Wisconsin, numerous logging railroads were established between 1881 and 1930 (Austin 1964). Often the railroads were located near water sources where the logs could be floated to mills or picked up and loaded on the cars. Some of the railroads incorporated other uses, including passengers, freight, and mail. Hunters and trappers often took "free rides" to the woods on logging railroads. At the end of the logging era, many of the logging railroads were simply abandoned. Some trains remained in commission or were moved to serve other industries. Around World War I, the price of scrap metal increased enough to prompt locals to dismantle trains for a profit.

In 1890 there were 5,583 miles of track in Wisconsin (Austin 1964). This number increased to a high of 7,963 miles in 1916. From that point, miles of railroad lines began to decrease.



Zinc miners pose with an ore bucket down in a mine, about 1910. Photograph courtesy of the Wisconsin Historical Society (Image ID 9029).

Early Logging Era

Nineteenth Century

Extensive stands of eastern white pine ranging from New England to western Canada attracted a new wave of settlement to northern Wisconsin in the mid-1800s. Many of the earliest lumberjacks came from the lumber camps in Maine or were French Canadians who had been involved in the fur trade. European immigrants were coming to the camps in the 1870s and 1880s, predominantly Swedes, Norwegians, Irish, and Germans (Austin 1964).

Pine was attractive for construction because it was straight-grained and easily worked as well as being the largest and longest-lived tree species in the region. Pine floated, making it easy to transport via the extensive network of rivers throughout northern Wisconsin (Mahaffey and Bassuk 1978). Access to the pine resource and sawmill construction in the far north was further hastened by the proximity to Lake Superior and easy transport to cities on the Great Lakes and to the east. The necessity of water transport prior to the establishment of railroads led to the organization of towns along river routes. One hazard of moving timber via water bodies was the log jams that sometime occurred. In 1869 an estimated 130 million board feet of timber was packed 20 to 50 logs deep and 2 miles long in the Chippewa River (Austin 1964).

Log train, Wausaukee, Wisconsin. Photo courtesy of Ann Hartnell, Graphic Impressions Photography LLC.

Logging near Rice Lake, ca. 1880. A group of men use a team of four horses to transport logs across snow-covered ground on a sled. Photograph courtesy of the Wisconsin Historical Society (Image ID 78303).

The timber industry attracted settlers and helped support other economic activities in the region, such as agriculture, mining, housing construction, and railroad building. Timber harvested in northern Wisconsin was sold throughout the United States and to Europe, South America, and the West Indies (Mahaffey and Bassuk 1978). Regionally, timber helped build the houses and farmsteads of the Great Plains and the Midwest prairies (Foust et al. 1983).

Of the estimated 130 billion board feet of pine in northern Wisconsin prior to Euro-American settlement, about 17 billion board feet remained in 1897 (Roth 1898). At that point, more than 8 million of the 17 million acres of forest were cut-over and generally burned. About 3 million acres were completely denuded. Several million acres contained only dead and dying trees. The greatest production of pine was between 1888 and 1894, with more than 3 billion board feet of lumber cut each year. Already there was concern over how the timber harvest and land clearing were affecting the regional climate, drainage channels, and future business interests for northern Wisconsin. For the 25 years between 1873 and 1897, approximately 60 billion board feet of lumber (mainly pine) were produced. Another 6 billion board feet of shingles, lath, etc., were also produced during this time. It was during this last quarter of the 19th century that Wisconsin was the highest lumber-producing state in the nation. By 1900 the declining supply of eastern white pine caused loggers to turn to other tree species, such as hemlock, cedar, and hardwoods.

Although land that was intensively harvested or cleared was widespread in most counties in the state, there was a distinct area of the state that was described as the "Cutover region" (WSPB 1939). In Wisconsin this included 26 counties and approximately 26,000 square miles (Figure 2.26). Land in the Cutover region was generally unsuitable for most southern Wisconsin agricultural crops due to the general poor quality of the soil and profusion of tree stumps. To make matters worse, farms were often isolated, without the conveniences of good roads, schools, rural free delivery of mail, telephone, and electricity. In order to “rehabilitate” northern Wisconsin, farmers were encouraged to relocate closer to other farms on more productive soils, and reforestation endeavors were taking place in the early 1900s.

Along with the removal of the forest resource came frequent fires, and some areas burned repeatedly. Between 1870 and 1930, over 500,000 acres burned each year. Some fires were intentionally started by loggers and farmers to remove the slash left from logging. Some of these intentionally set fires burned out of control, while others started on their own. The worst fire year on record was in 1908 when approximately 1,400 fires burned 1.2 million acres. In 1897 a forestry commission was created by the legislature to study and address forest conservation, including fire protection for forests in the state.

Twentieth Century

In 1903 the Wisconsin Department of State Forestry was created, and 40,000 acres of forestland was reserved as an initial effort to help counter the effects of logging the north woods. In 1910 the U.S. Department of Agriculture created the Forest Products Laboratory (FPL) in Madison, Wisconsin. The FPL was established for wood products research including the most efficient use of wood. In 1936 the U.S. Forest Service conducted the first comprehensive forest inventory of the forest resource within the Great Lakes region. Mature timber was in short supply, and recovery of ***second growth*** was still lagging. A large volume of poor quality and rotten trees remained. The authors of the forest inventory, Cunningham and Moser (1938), divided Wisconsin into four economic units (Figure 2.27). They estimated all of Wisconsin to be 48% forested. The northwestern portion of the state was considered to be 79% forested while the northeast, central, and southwest were 82, 30, and 31% forested, respectively.

Wisconsin had an estimated 17 million acres of forest in the 1930s (Cunningham and Moser 1938). The early successional aspen-birch forest type was in the majority with 31% of the forestland. Another 21% of the land was deforested. Of the land considered to be forested, 48% was restocking land. Table 2.6 shows a breakdown of the available forest types according to size class. For all of Wisconsin at this time, an estimated 16.6 billion board feet of sawtimber was available. Nearly 12 billion board feet was hardwoods. In addition, there were approximately 6

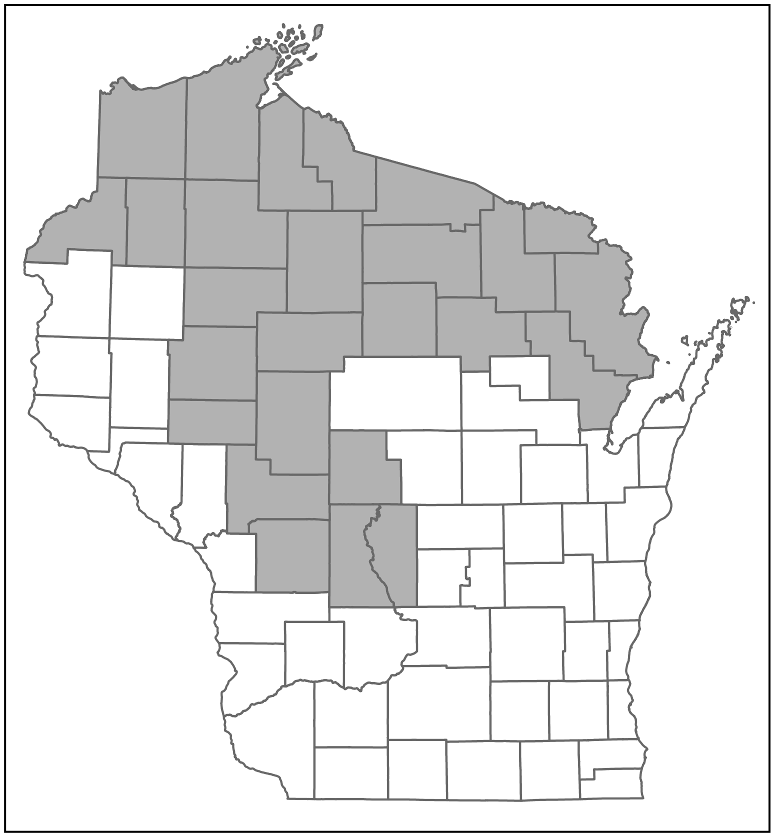


Figure 2.26. *Counties of the Cutover region (Wisconsin State Planning Board 1939).*

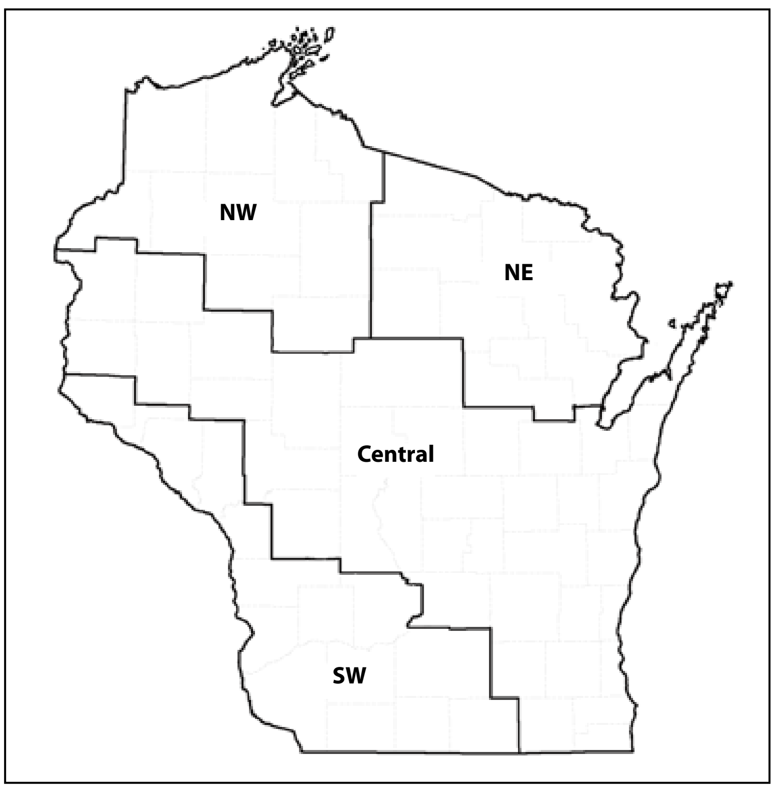


Figure 2.27. *Economic units of Wisconsin in 1938, established for the first Forest Inventory and Analysis survey (Cunningham and Moser 1938).*

Table 2.6. *Acreage of Wisconsin forestland by forest cover type and size class, 1936.*

Forest cover type	Total acres	Old-growth sawtimber	Second-growth sawtimber	Cordwood	Restocking land
White pine	215,000	74,000	54,000	45,000	42,000
Red pine	86,000	10,000	24,000	25,000	27,000
Jack pine	665,000	2,000	25,000	198,000	440,000
Spruce-fir	638,000	3,000	20,000	214,000	401,000
Spruce swamp	325,000	–	–	57,000	268,000
Tamarack swamp	203,000	3,000	1,000	38,000	161,000
Cedar swamp	201,000	3,000	15,000	77,000	106,000
Nonproductive swamp	50,000	–	–	–	50,000
Northern hardwoods	2,745,000	771,000	456,000	420,000	1,098,000
Oak	1,736,000	214,000	392,000	605,000	525,000
Ash-elm	674,000	102,000	105,000	248,000	219,000
Aspen-birch	5,317,000	14,000	62,000	929,000	4,312,000
Scrub forest	552,000	49,000	7,000	18,000	478,000
Deforested[a]	3,539,000				
All forest types	**16,946,000**	**1,245,000**	**1,161,000**	**2,874,000**	**8,127,000**

Source: Data from Cunningham and Moser (1938).
[a]796,000 acres of grass, 1,374,000 acres of brush and marsh, 1,369,000 acres of lightly wooded pasture.

million cords of high-grade pulpwood along with another 102 million cords of other tree species.

Wisconsin's Resource Characterization and Use

This section identifies Wisconsin's natural resources and describes their uses. Renewable resources, such as forests, are able to rebound in some ways from exploitation, although for some renewable resources, it may take many years. For nonrenewable resources, such as minerals and quarries, depletion can never be counteracted, and losses are permanent. Resource use will have social and economic effects depending on how efficiently it is used. In addition, society's needs, tastes, and values may change, affecting the future of the resource base. Technological advances may also transform the way resources are developed.

Wisconsin is fortunate to have an extensive and varied resource base that provides the state's inhabitants with abundant social, economic, and recreational benefits. Wisconsin is comprised of approximately 35 million acres of land and water. Within its boundaries, 16.7 million of these acres are forested, 15.2 million acres are farmland, and 1.2 million acres are lakes (NASS 2010d, USFS 2010, Wisconsin DNR 2010). Much of the northern half of Wisconsin is owned by various forms of government. Tourists are attracted to the area for the scenic beauty and recreational opportunities. Residents of northern Wisconsin enjoy both the recreational opportunities and the economic benefits of the area's natural resources.

Agriculture

Wisconsin farm numbers have been decreasing since World War II (Figure 2.28). Since 1950 approximately 96,000 farms have been lost (NASS 2010e). This is more than the total number of farms present in the state today. Between 1950 and 1991, the average size of farms slowly increased from 136 acres to 222 acres, then began shrinking slowly to 195 acres in 2009. The total land in farms has also been steadily decreasing. In 1950, 23.6 million acres of Wisconsin land was farmland. By 2009, farmland acreage had decreased to 15.2 million acres.

Wisconsin has been a leader in dairy farming since the late 1800s. Milk production especially has progressively increased over the past century. Figure 2.29 shows over 50 years of Wisconsin's milk production compared to other leading milk-producing states. Wisconsin led the nation in milk production until 1993 when California took the lead, holding it up to the present.

Parallel to an increase in total milk production is the growth in milk produced per cow. In 1950 the average cow produced 6,850 pounds of milk a year (NASS 2010c). By 1970 that value had increased to 10,163 pounds a year. The

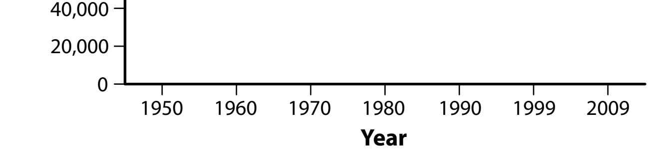


Figure 2.28. *Number of Wisconsin farms between 1950 and 2009 (NASS 2010d).*

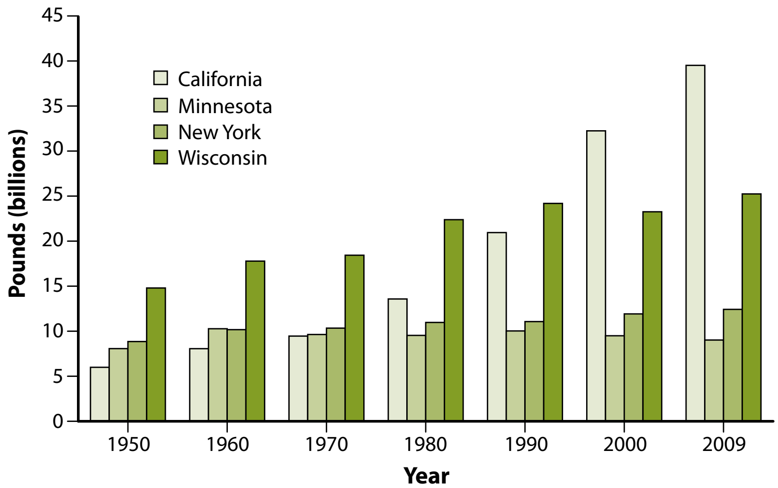


Figure 2.29. *Annual milk production of the leading dairy states for 1950–2009 (NASS 2010c).*

average cow today in Wisconsin is producing 20,079 pounds of milk per year. The increase in efficiency can be attributed to advances in breeding and dairying methods.

Current Conditions

In 2008 there were 78,000 farms in Wisconsin (NASS 2009). Cash receipts for farm commodities in 2007 were $9 billion. Of the total, 70% came from livestock and livestock products, and 30% came from crops. This value was up 60% from the 1997 cash receipt total. As of 2008, Wisconsin led the nation in production of cheese, dry whey, mink pelts, cranberries, corn for silage, and snap beans for processing. Table 2.7 details the commodities of which Wisconsin was a leading U.S. producer in 2008.

Price trends

Grain and hay prices (in constant dollars) decreased in Wisconsin every decade from 1950 to 2000, except for the period 1970–80 (Table 2.8). From 2000 to 2009 this trend reversed. Corn price increases could be expected due to the large increase in corn ethanol production. Other crop prices may have increased as a result of decreasing supply with more cropland being put into corn.

Conversion of Agricultural Land

Acreage designated as pastureland and grazed forestland has generally been decreasing in Wisconsin. A decrease in these lands is a partial contributor to the reforestation of Wisconsin. One of the results of an end to grazing is conversion of idle pastureland to forestland as tree seedlings are given the opportunity to grow rather than being trampled or eaten. Former grazed wooded areas also will fill in with vegetation after grazing has ceased. Table 2.9 shows the changes in acreage of grazing lands since 1949. Many woodlots are still grazed because of the tax laws (and tradition). It's the open pastures that seem to have disappeared. And the vegetation that "fills in after grazing has ceased" is often exotic honeysuckles, buckthorns, and multiflora rose.

Table 2.7. *Wisconsin's leading agricultural commodity production, 2008.*

Commodity	Rank among states	Unit	Wisconsin (thousands)	Percent of U.S.	U.S. total (thousands)
Milk	2	Lbs.	24,472,000	12.9	189,992,000
Butter	2	Lbs.	361,041	22.0	1,1,644,078
Cheese	1	Lbs.	2,524,077	25.4	9,934,530
Dry whey	1	Lbs.	304,753	29.0	1,049,881
Milk cows	2	Head	1,255	13.4	9,333
Milk goats	1	Head	40	11.9	335
Mink pelts	1	Pelts	910.1	32.7	2,787
Corn for silage	1	Tons	15,313	13.7	111,619
Oats	2	Bushels	11,780	13.3	88,635
Potatoes	3	Cwt[a]	25,730	6.2	412,742
Maple syrup	4	Gallons	130	8.0	1,635
Cranberries	1	Bbl[b]	4,470	56.8	7,865
Mint for oil	5	Lbs.	208	2.6	7,898
Carrots	2	Tons	77.3	19.1	405
Sweet corn for processing	2	Tons	652	23.0	2,832
Green peas for processing	3	Tons	76	18.5	412
Snap beans for processing	1	Tons	327	40.5	808
Cucumbers for pickles	4	Tons	39	7.0	566

Source: Adapted from *2009 Wisconsin Agricultural Statistics*, "Wisconsin's Rank in the Nation's Agriculture, 2008" table (NASS 2009).
[a]Cwt = hundred weight, or 100 pounds
[b]Bbl = barrel, or 100 pounds of harvested cranberries

Table 2.8. *Percent change in grain and hay prices for the decades between 1950 and 2009.*

Grains	1950–60	1960–70	1970–80	1980–90	1990–00	2000–09
Barley	-48%	-21%	30%	-54%	-52%	88%
Corn (for grain)	-48%	7%	10%	-57%	-35%	59%
Oats	-35%	-10%	12%	-60%	-39%	67%
Wheat	-29%	-39%	45%	-60%	-48%	77%
Hay (all dry)	-37%	-12%	10%	-25%	-42%	78%

Source: USDA National Agricultural Statistics Service (NASS 2010e).

Table 2.9. *Changes in acreage (thousand acres) of pastureland, grazed forestland, and nongrazed forestland of Wisconsin, 1949–2002.*

Land class	1949	1959	1969	1978	1987	1997	2002
Pasture	2,432	3,182	2,526	1,914	2,079	1,844	2,003
Grazed forestland	6,624	2,905	2,210	1,748	1,393	1,284	1,201
Non-grazed forestland	10,290	12,659	12,682	13,092	13,665	14,417	14,500

Source: USDA Economic Research Service (2010a).

Between 2004 and 2008, 741,337 acres of agricultural land were sold (NASS 2009). Of this, 126,074 acres (17%) were diverted to other uses such as urban development, housing development, and recreation, including golf course development. The remaining 615,263 acres (83%) continued in agricultural use. Agricultural land that has been diverted to some other use is sold for a higher price compared to land that continues in agricultural use. The average price of agricultural land sold in 2010 that remained agricultural land was $3,861 per acre (NASS 2010a). The average price of agricultural land sold in 2010 that changed use was $5,909 per acre.

Minerals

In 2007 there were 155 mining establishments in Wisconsin with 3,280 employees and an annual payroll of $162 million (USCB 2010b). The majority of mining income is from nonmetallic mineral mining and quarrying. Crushed and broken limestone mining and quarrying alone accounted for 46 establishments, 1,773 employees, and an annual payroll of $78 million.

Recent Mineral Production

Wisconsin's principal nonfuel minerals in 2006 were crushed stone, construction sand and gravel, industrial sand and gravel, lime, and dimension stone (USGS 2006). The value of nonfuel mineral production in Wisconsin for that year was an estimated $566 million (Table 2.10). The state remained 34th in rank among the 50 states in total nonfuel mineral production value and accounted for 1% of the U.S. total value. Wisconsin was one of the nation's top producers of dimension stone and industrial sand and gravel that year.

Crushed stone and construction sand and gravel were Wisconsin's leading nonfuel minerals in 2006 (Table 2.10), accounting for more than 36% and 32%, respectively, of the state's reportable total nonfuel raw mineral production value (USGS 2006). These were followed by industrial sand and gravel, representing about 13% of the total value, lime with about 12.5%, and dimension stone with about 6% of the state's total nonfuel mineral value. Aggregate mining (sand, gravel, and crushed stone) occurs in virtually every county of Wisconsin. Construction sand and gravel output declined by 8% from 2005 to 2006.

Currently, no metallic mines operate in the state. The last was the Flambeau Mine in Rusk County near Ladysmith. It began in 1993 and resulted in a 32-acre pit where copper and gold ore were extracted. Operations ended in 1997, and a reclamation project ensued. The mine pit was filled, and the site was reshaped and planted with native species. Wetland restoration began on the site in 1998.

Wisconsin has recently seen a dramatic increase in the number of sand mines. Wisconsin sand is ideal for the process of "hydrofracking" used by oil companies to recover gas and oil from rock formations. Wisconsin sand used for "hydrofracking" is being sent all over the country. As of February 2012, there were over 47 active, inactive, or proposed sand

Table 2.10. *Nonfuel mineral production quantity and values for Wisconsin, 2006.*

Mineral	Quantity (1,000 metric tons)	Value (1,000 dollars)
Crushed stone	35,800	$204,000
Construction sand and gravel	39,600	$182,000
Lime	922	$70,700
Industrial sand and gravel	2,450	$74,100
Dimension stone	297	$35,400
Peat	–[a]	–[a]
Gemstones	–[b]	$6
Total		**$566,000**

Source: *2006 Mineral Yearbook: the Mineral Industry of Wisconsin* (USGS 2006).
[a]Withheld to avoid disclosing company proprietary data.
[b]Not available

mines in the state; however, the number has been increasing rapidly. The dramatic increase in sand mines bears watching because not much is known on the potential impacts of these mines on Wisconsin's natural resources. See Chapter 5, "Current and Emerging Resource Issues," for more details.

Future Mineral Development

The Sulfide Mining Moratorium Bill (SB3) was passed in April 1998. This bill requires future sulfide mining interests to provide an example of one decommissioned sulfide mine that has proven to be nonpolluting for a 10-year period. Additional requirements that must be met by mining applicants, along with more stringent groundwater regulations, will have an effect on all future mining proposals in Wisconsin.

Recreation

Since Wisconsin's landscape and climate vary regionally, the state offers different recreational opportunities, depending on location. The role of recreation in the state and regional differences in recreational opportunities are discussed below, emphasizing public lands and focusing on three main user groups engaged in the following activities:

- Hiking, biking, camping, canoeing, bird watching, etc.
- Hunting and fishing
- Motorized activities, including snowmobiling, motor boating, off-road driving with an ATV, and jet skiing

This section is based, in part, on *The 2005–2010 Wisconsin Statewide Comprehensive Outdoor Recreation Plan* (WDNR 2006).

Participation in Recreational Activity

Activities with the highest participation rates by Wisconsin residents are generally those that require the least expertise and equipment. Walking for pleasure, viewing/photographing natural scenery, visiting nature centers, driving for pleasure, and viewing/photographing wildlife were the top five activities for the years 1999–2004, with 57%–86% participation rates (Table 2.11).

Table 2.11. *Wisconsin residents' recreational activity participation rates, 1999–2004.*

Activity	Participation rate[a]
Walking for pleasure	85.8%
Viewing/photographing natural scenery	67.5%
Visiting nature centers, etc.	65.3%
Driving for pleasure	60.3%
Viewing/photographing wildlife	57.0%
Picnicking	56.6%
Bicycling	49.3%
Viewing/photographing wildflowers, trees, etc.	50.0%
Swimming in lakes, streams, etc.	45.8%
Viewing/photographing birds	40.9%
Fishing – freshwater	40.7%
Gathering mushrooms, berries, etc.	39.5%
Visiting wilderness or primitive area	38.3%
Fishing – warmwater	37.0%
Motor boating	36.4%
Day hiking	35.0%
Camping – developed	32.3%
Viewing/photographing fish	28.1%
Golfing	25.9%
ATV off-road driving	23.4%
Canoeing	20.5%
Mountain biking (off-road)	20.4%
Hunting (big game)	19.2%
Snowmobiling	18.3%
Mountain biking (single track)	18.0%
SUV 4-wheel driving (off-road)	17.7%
Camping – primitive	16.0%
Hunting (small game)	14.5%
Fishing – coldwater	13.9%
Cross-country skiing	11.4%
Fishing – ice	11.4%
Hunting – upland birds	10.5%
Horseback riding	9.8%
Downhill skiing	9.7%
Backpacking	6.9%
Sailing	4.9%

Source: *2005–2010 Wisconsin Statewide Comprehensive Outdoor Recreation Plan* (SCORP) (WDNR 2006).
[a]Average percentage of participation rate over a five-year period.

The following factors influence who participates in different types of recreation (WDNR 2006):

- Age: Involvement in outdoor activities differs across age groups. Younger adults are more likely to downhill ski, canoe, and camp in tents than older adults. Peak participation rates for hiking, nature photography, golfing, and sailing are found among people in their 30s. Middle-aged adults have higher participation rates in cross-country skiing. Overall, participation in outdoor recreation wanes after 50 years of age. At this life stage, older adults are more likely to engage in nature study and bird watching than other age groups.
- Gender: There are also predictable gender differences in outdoor recreation. For example, women are more likely than men to partake in bird watching, walking for pleasure, picnicking, and nature photography. Men are more likely than women to hunt, fish, camp, golf, ride mountain bikes and ATVs, backpack, and go canoeing, sailing, and motor boating.
- Disabilities: People with disabilities have lower participation rates in approximately half the activities listed in Table 2.11. Involvement is about the same for people with disabilities as for those without disabilities in nature study/bird watching, wildlife viewing, nature photography, hunting, and camping with an RV.
- Income: Income can be a deciding factor in recreation. Income appears to be related to participation rates of

Sailboat on Lake Superior off Bayfield. Photo by Wisconsin DNR staff.

all outdoor activities other than wildlife viewing, nature study and bird watching, hiking, and mountain biking. Snowmobiling appears to be more popular with those in the middle household income bracket ($20,000–$50,000). People in the upper income range ($50,000) show higher participation rates in sailing and downhill skiing.

- Education: There also appears to be a connection between education and outdoor recreation. For example, those with lower educational attainment are more likely to take part in hunting, snowmobiling, and ATV riding. Outdoor activities such as cross country skiing, backpacking, and boating are more common among those with a higher educational attainment, which has a higher participation rate from those with four or more years of college. Notable exceptions are warmwater and coldwater fishing, which do not seem to show a relationship to education.

Fishing and Hunting

According to a report from the U.S. Fish and Wildlife Service (USFWS 2006), in 2006, 1.4 million people, age 16 or older, fished Wisconsin's waters, and 697,000 hunted the land (see Table 2.12). Of the anglers, 73% were residents while the remaining 27% were nonresidents. Of the hunters, 93% were residents, and 7% were nonresidents. The majority of hunters (92%) hunted big game, nearly one-third (32%) hunted small game, and 11% hunted migratory game birds.

There were 20.8 million total days of fishing, 82% of which were by state residents (USFWS 2006). There were 10.1 million days of hunting, 96% of which were contributed by state residents. Anglers spent over $1.6 billion in Wisconsin in 2006, purchasing everything from food and lodging to fishing equipment and licenses. Hunting expenditures totaled $1.3 billion.

Wildlife Watching

In 2006, two million people, aged 16 years or older, participated in wildlife-watching activities such as feeding, photographing, and observing fish and wildlife in Wisconsin (Table 2.12). That same year, there were 5.5 million wildlife-watching activity days in the state. Residents contributed 68% of these days while nonresidents contributed the remaining 32% (USFWS 2006). Total expenditures by resident and nonresident wildlife watchers totaled $745 million. Of this, $260 million was related to the trip (food, lodging, transportation, etc.), $227 million was spent on equipment, and $257 million went to wildlife plantings, magazine subscriptions, books, membership dues, and contributions.

Recreation by Wisconsin DNR SCORP Planning Region

Wisconsin is a popular outing and vacation destination not only for its residents but also for others in the Midwest as well. Regional recreation participation is based on a number of factors, including environmental resources, resident demand, and seasonal variations. Eight planning regions were identified in *The 2005–2010 Wisconsin Statewide Comprehensive Outdoor Recreation Plan* (SCORP): the Great Northwest, the Northwoods, the Upper Lake Michigan Coastal, the Lower Lake Michigan Coastal, the Southern Gateways, the Mississippi

Table 2.12. *Wildlife-associated recreation in Wisconsin (age 16 or older), 2006.*

	Participation (thousands)	Activity days (thousands)	Expenditures (thousands)
Fishing	1,394	20,823	$1,647,035
Hunting	697	10,059	$1,312,128
Wildlife watching	2,039	5,547	$ 744,689

Source: 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Activities (USFWS 2006).

River Corridor, the Western Sands, and the Lake Winnebago Waters regions (WDNR 2006). These eight regions have been grouped into six major regions as follows for analysis of recreation participation rates:

- The Great Northwest region consists of the nine counties of northwestern Wisconsin. They contain an abundance of natural resources that offer an exceptional amount of outdoor recreational opportunity. This region has the highest participation rate for boating (56%), freshwater fishing (49%), hunting (37%), canoeing (29%), snowmobiling (27%), and wilderness activity, including backpacking and hiking. This region has very low participation rates for more urban activities such as surfing, dog walking, or tennis. These counties have many visitors and second homeowners from the Twin Cities area in Minnesota as well as from Duluth and the Eau Claire/Chippewa Falls area (Marcouiller and Mace 1999).
- The Northwoods and Upper Lake Michigan Coastal region consists of 15 counties of northeastern and north central Wisconsin. With its numerous high quality lakes and rivers, the region supports a large number of water-based recreation opportunities. Tourism is an important and growing business in the region as increasing numbers of visitors from Milwaukee, Madison, and Chicago make use of the environment here. The region is also heavily influenced by its association with Lake Michigan and has the highest participation in snow and ice-related activities (50%) as well as cross-country skiing (19%), snowshoeing (18%), rowing, snorkeling, Great Lakes fishing, and sailing.
- The Lower Lake Michigan Coastal region consists of the eight mostly urban counties of far southeastern Wisconsin (WDNR 2006). The urban influence of Milwaukee and its surrounding suburbs has created demand for distinctly urban recreation facilities while proximity to Lake Michigan drives a demand for water-based activities. This region has the highest participation rates for visiting beaches (51%) and swimming pools (43%), jogging (33%), and kayaking (7%). It has some of the lowest rates for snow and ice-related recreation.
- The Southern Gateways region consists of the 10 counties of south central Wisconsin. This region contains a variety of environments, the combination of which provide a wide array of recreational opportunities. The central presence of Madison impacts much of the Southern Gateways region. As urban populations increase, so too does the demand for traditionally urban-based recreation. This region has the highest participation in walking for pleasure (89%), picnicking (63%), and nature-based educational programs (23%). It has some of the lowest rates of snow- and water-based recreation.
- The Mississippi River Corridor consists of the 10 counties of southwestern and west central Wisconsin. The Mississippi River running along the region's western border is the primary recreational resource in the region. It is also very rural with a high proportion of land in agriculture. Suburban development associated with the greater Twin Cities metropolitan area in St. Croix and Pierce Counties continues to impact recreation supply and demand across the area. This region has the highest participation rates in visiting farms (40%), developed camping (31%), off-road ATV use (35%), and golf (31%).
- The Western Sands and Lake Winnebago Waters region consists of the 20 counties in the central part of the state. Outside of northern Wisconsin's abundant park and water resources, this region has the largest amount of public lands and water in the state. Lake Winnebago, the largest lake in the state, is a major recreational resource within the region. Urban and suburban development within the region continues to grow and impact recreational demand for distinctly urban activities. This region has the highest participation rates for bicycling (56%), warmwater fishing (45%), visiting water parks (43%), off-road driving (35%), and horseback riding (12%).

Supply of Recreational Settings

Setting aside land for public enjoyment is a long-standing tradition in Wisconsin. Among the federal, state, and local (county and municipal) governments, 16% of the land in Wisconsin is public conservation and recreation land. Table 2.13 shows the various kinds of public conservation and recreation grounds found in Wisconsin. The Northwoods and Upper Lake Michigan Coastal region has the greatest percentage of public use land, with 29.2% of its 8.3 million acres of land in public conservation and recreation ownership (WDNR 2006). For the remaining regions, public conservation and recreation land is 26.7% of the Great Northwest region, 11.7% of the Western Sands and Lake Winnebago Waters region, 6.4% of the Lower Lake Michigan Coastal region, 4.3% of the Southern Gateways region, and 3.9% of the Mississippi River Corridor region (the lowest in the state).

Contribution of Recreation to State Economy

Forest-based recreation plays an important role in people's lives. Many family traditions depend on forest-based opportunities like hunting and fishing. Wisconsin's growing human population will potentially increase demand for additional recreation lands and facilities. Tourism and forest management are mainstays to local economies. On an annual basis, forest-based recreationists spend approximately $2.5 billion within Wisconsin communities (Marcouiller and Mace 1999). This spending stimulates the economy further, and it is estimated that forest-based recreation is a $5.5 billion industry (WEDI 2004).

Table 2.13. *Public conservation and recreation lands of Wisconsin, 2004.*

Owner	Acreage	Percent of Wisconsin land	Percent of public cons. & rec land
Federal government	1,759,030	4.9	30.4
Wisconsin DNR			
State forests and wild rivers	624,470	1.7	10.8
State natural and park areas	141,246	0.4	2.4
State fisheries and wildlife	600,978	1.7	10.4
County parks and forests	2,594,625	7.2	44.9
City, town and village Parks	62,004	0.2	1.1
Total public conservation and rec. land	5,728,353	16.1	
Total Wisconsin land	**35,911,907**		

Source: *The 2005–2010 Wisconsin Statewide Comprehensive Outdoor Recreation Plan* (SCORP) (WDNR 2006).

Recreation in Government Budgets

There is a cost associated with maintaining Wisconsin's natural resources. For fiscal year 2010, the Wisconsin Department of Natural Resources annual budget was $576 million. A significant portion of the DNR budget is related to outdoor recreation expenditures. Programs and services receiving the greatest shares were debt service and development, water, and lands (Table 2.14). In addition to maintaining the natural resources, the DNR purchases other lands each year that are made available to the public. In comparison to its contribution to the state economy, including fishing and hunting, recreation expenditures are relatively small.

Table 2.14. *Wisconsin Department of Natural Resources expenditures, Fiscal Year 2010.*

Program	Expenditure (thousands)
Lands	
Endangered Resources	5,718
Facilities and Lands	10,239
Lands Operations	1,039
Parks and Recreation	9,384
Southern Forests	5,409
Wildlife Management	19,564
Lands – Total	**$61,352**
Forestry	
Forestry – Total	**$54,696**
Air & Waste	
Air Management	16,284
Cooperative Environmental Assistance	1,359
Waste and Materials Management	7,651
Remediation & Redevelopment	11,644
Air & Waste operations	456
Air & Waste – Total	**$37,395**
Enforcement & Science	
Law Enforcement	30,720
Science Services	10,941
Enforcement/Science operations	886
Enforcement & Science – Total	**$42,547**
Water	
Watershed Management	34,496
Fisheries Management	25,461
Drinking Water/Groundwater Management	12,070
Water operations	1,077
Water – Total	**$73,103**
Other	
Resource aids	$43,675
Environmental aids	$52,557
Debt Service and Development	$149,132
Administration	$4,760
Customer and Employee Services	$56,776
Wisconsin DNR total	**$575,993**

Forest Products

Wisconsin has a long history of using forest products for medicinal, sustenance, economic, and aesthetic purposes. It is difficult to assess the true volume of many collected forest products since they are often collected by individuals and used within the household. This section identifies some of the products that provide social and economic benefits to people in the state.

Timber

Natural resource-dependent areas, such as those in the northern portion of the state, rely on forests for much of their economic well being. This may be achieved directly via employment and income from timber sales and other forest products or indirectly via the visitors who travel to the area for outdoor recreation. The forest products industry has been active in Wisconsin since the mid-1800s and continues today with an emphasis on ***sustainable forest management***.

■ **Mid–Twentieth-Century Perspective.** Northern Wisconsin forests started to recover from the Cutover and fires of the late 19th and early 20th centuries in the early 1930s when state-organized wildfire suppression began. At that time, the sawtimber supply was limited while the pioneer species aspen had become established in the large cut-over and burned areas. From 1933 to 1942 the Civilian Conservation Corps planted 265 million trees in Wisconsin. As late as the 1968 Forest Inventory and Analysis survey, about 50% of the forest stands on timberland in Wisconsin were less than 40 years old (Spencer and Thorne 1972).

During the 1950s, energy use increased, and fuel use replaced labor. Harvest methods were further mechanized with the use of chainsaws, skidders, tractors, and hydraulic shears. Wood residue that accumulated at sawmills was generally burned in the open and not used for energy in the mills since the use of new technologies and petroleum fuels was cheaper than burning wood residue to operate the mills.

In 1956 the U.S. Forest Service conducted the second survey of the forest resource within Wisconsin, dividing Wisconsin into five survey units for purposes of analysis in the inventory (Figure 2.30). Several changes were made in the way the inventory was conducted from the previous survey 20 years earlier, although metrics were generally comparable. Stocking levels, volume, growth, reforestation, and annual allowable cut for all species had increased between 1936 and 1956. Changes in softwood stands, however, were a concern at the time. Softwood acreage remained low relative to historical forest type acreage, but pine acreage had increased slightly between inventories. Spruce-fir acreage had declined, and overall actual harvest of softwoods exceeded the annual allowable cut. There was also a large volume of cull trees. Stone and Thorne (1961), the authors of the survey report, estimated all of the state to be 45% forested, down from 48% in 1936. The reason behind the apparent decrease in forestland can be attributed to conversion of forestland to other uses to some extent; however, reclassification was the primary source of the apparent change. Several hundred thousand acres of "stump pasture," categorized as forestland in 1936, were reclassified as pasture (nonforest) in 1956 with no real change in land use.

An estimated 15.6 million acres of forestland was present in Wisconsin in 1956, 15.4 million of which was considered commercial forestland (Table 2.15). The aspen-birch forest type was still the major type, accounting for 30% of the commercial forestland, although it was decreasing (Stone and Thorne 1961). Being early successional species, aspen and birch invaded logged-over areas, especially those that had been burned. In the mid-1950s, some aspen-birch stands began to mature and were ready for commercial logging. With the increase in demand for pulpwood, aspen became a preferred tree species. Logging along with natural succession to other tree species contributed to the decline of this forest type.

Another 17% of the commercial forestland was northern hardwoods in 1956 (Stone and Thorne 1961). The acreage of this forest type changed little since 1936. Oak also covered 17% of Wisconsin's commercial forestland and was the dominant sawtimber type in 1956. See Table 2.15 for a breakdown of the forest types according to stand size class. For all of Wisconsin at this time, an estimated 16.3 billion board feet of sawtimber was available, of which over 12 billion was hardwoods. In addition, there were approximately 58 million cords of ***growing stock*** available.

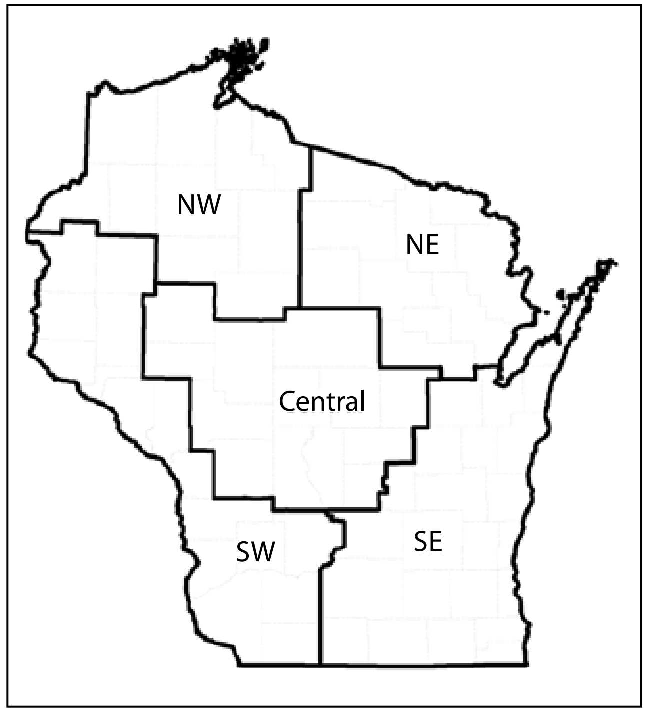


Figure 2.30. *Forest Inventory and Analysis survey units of Wisconsin in 1956 (adapted from Stone and Thorne 1961).*

Timber harvesting in Wisconsin changed substantially between 1950 and 1970 (Cleveland 1991). The Clean Air Act of 1970, higher fuel prices in the early 1970s, and improved technology encouraged the use of wood residue for mill energy. During the 1970s, the surge in energy prices caused some mills to close and others to become more efficient. During this time, technological improvements allowed some by-products of production that were once considered waste to be chipped for pulp or converted to goods such as particleboard.

Importance of the Timber Industry in Wisconsin's Economy. In 2007, Wisconsin businesses and government employed 3.56 million workers earning $135 billion with an industry output of $482 billion (WDWD 2010). All manufacturing (including manufacturing, primary wood processing, secondary wood processing, and pulp and paper) provided the highest output (36%) while the services segment of the economy employed the greatest number of workers (39%) and highest total employee compensation (33%).

The wood-based industries, which include primary wood processing, secondary wood processing, and pulp and paper, constitute a sizable segment of total manufacturing and the state economy as a whole. In 2006 industry output from wood-based industries of $20.5 billion represented 5.4% of total state output and 13.3% of all manufacturing output (WDWD 2010). The 65,694 jobs in wood-based industries were 1.8% of the state total and 13.3% of the manufacturing sector. Wood-based industry employee compensation of $3.1

Table 2.15. *Acreage of commercial forestland by forest type and stand size class, 1956.*

Forest type	Total	Sawtimber	Pole timber	Seedlings/saplings
	(thousand acres)			
White pine	174	117	28	29
Red pine	148	39	14	95
Jack pine	692	16	187	489
Spruce-fir	373	2	102	269
Black spruce	260	–	34	226
Tamarack	185	1	43	141
Cedar	223	17	103	103
Lowland hardwoods	941	246	462	233
Northern hardwoods	2,663	821	894	948
Oak	2,573	855	933	785
Aspen-birch	4,611	19	2,123	2,469
Nonstocked	2,553			
All forest types	**15,396**	**2,133**	**4,923**	**5,787**

Source: Stone and Thorne (1961).

billion represented 2.2% of the state total and 12.6% of all manufacturing. Average income in the wood-based industries was $46,570 compared with a state average of $38,169 for all sectors of the economy.

Timber Supply. Since the 1960s, acreage in Wisconsin's forestland has been increasing. The main contributor to this trend is the reestablishment of forests on marginal agricultural lands. One such regeneration effort is within the federal Conservation Reserve Program (CRP) through which farmers are compensated for setting aside agricultural lands for some other useful purpose. In 1968 Wisconsin had approximately 14.9 million forested acres, which had increased to 16 million by 1996 (Schmidt 1997) and 16.7 million by 2008 (Perry 2009).

In 2008, northern Wisconsin contained a higher percentage of forested land compared to the rest of the state. The northeastern part of the state is 74% forested and the northwestern part is 70% forested (Perry 2009). Southeastern Wisconsin is the most urbanized and agricultural part of the state and therefore contains the least forestland (13%). Central and southwestern Wisconsin are 43% and 34% forested, respectively.

There were approximately 20.9 billion cubic feet of growing stock volume on timberland in the state in 2008 (see Table 2.16). The majority of this volume (74%) was attributed to hardwoods. Within this growing stock volume about 61 billion board feet was sawtimber, about 67% of which was hardwood. The state's timber resource experienced a net average annual growing stock growth of 586 million cubic feet between 2003 and 2008 (Table 2.17). The majority of this growth (70%) was in hardwood growing stock trees. Sawtimber grew a net annual average of 2.3 billion board feet, of which about 66% was in hardwoods.

In 2008, 46,592 acres of forestland were sold throughout Wisconsin. Of this, 8,859 acres (19%) were diverted to other uses such as housing or pastureland. The remaining 37,773 acres (81%) continued in forestland. Forestland appears to have higher economic value when its use is changed. The average price for forestland that continued in forestland was $2,319 per acre. However, when the forestland was diverted to some other use, the average price increased to $2,870 per acre (NASS 2010b). This value difference is probably due to location and desirability for residential development.

Table 2.16. *Volume of softwood and hardwood growing stock and sawtimber volume in Wisconsin, 2008.*

Group	Growing Stock (1,000 cubic feet)	Sawtimber (1,000 board feet)
Softwoods	5,536,762	20,412,608
Hardwoods	15,406,822	40,830,134
Total	**20,943,584**	**61,242,742**

Source: Forest Inventory and Analysis, 2010 (USFS 2010).

Table 2.17. *Average net annual growing stock and sawtimber growth of softwoods and hardwoods in Wisconsin, 2003–2008.*

Group	Growing stock (1,000 cubic feet)	Sawtimber (1,000 board feet)
Softwoods	176,539	768,001
Hardwoods	409,523	1,503,965
Total	**586,062**	**2,271,966**

Source: Forest Inventory and Analysis, 2010 (USFS 2010).

Timber Demand. Today nearly 100% of each tree can be used to manufacture wood or paper products or converted to energy. For example, tree bark, wood shavings, and sawdust can be burned for heat or to produce steam in generating electricity. Wood chips can be processed into pulp to make paper or manufactured into particleboard and composite panels.

General indicators of timber demand and sustainability are provided by annual timber removals and their comparison to net annual growth. Removals are defined as trees removed for roundwood forest products, the unused portion of cut trees plus unused trees killed by logging, trees removed but not utilized for products, and trees left standing but "removed" from the timberland classification by land use change. Net average annual removals from growing stock were 327 million cubic feet between 2003 and 2008 (Table 2.18). The majority of removals (70%) were from hardwood growing stock trees. Removals-to-growth ratios were 39% for softwoods, 63% for hardwoods, and 56% for the total growing stock volume (USFS 2010). Sawtimber average annual removals were 949 billion board feet of which about 78% were from hardwoods. Removals-to-growth ratios for softwoods, hardwoods, and total sawtimber volume were 27%, 49% and 42%, respectively.

The demand for Wisconsin's timber resource can also be analyzed by looking at actual harvest volumes from state forests over time. From 1946 through the mid-1980s, pulpwood production increased steadily for all of the species groups in Figure 2.31. After the mid-1980s, however, production of pioneer species (aspen and birch) leveled off and began to decline. This is a result of heavy consumer demand and high natural mortality levels of these short-lived species. As pioneer aspen and birch are replaced by other species, forests age, and demand for wood products continues to grow worldwide, the forest industry in Wisconsin has turned to more softwoods and other hardwoods to meet the demand.

Price Trends. The market value of the timber resource will depend on which species are available, in what size/product classes, and subsequent harvest and transportation costs. Regional differences will have an effect on timber harvest in Wisconsin. Overall, 82% of the state's forestland area is classified as hardwood forest type, with oak-hickory being the most dominant individual forest type (USFS 2010). The remaining 18% of the forestland is classified as conifer with a breakdown as follows: 9% pine, 7% swamp conifer, and 2% spruce-fir.

Stumpage price trends are shown for individual species in Table 2.19 for the decades between 1960 and 2010. Figure 2.32 shows the average (inflation-adjusted) sawtimber value for softwood and hardwoods species for the same period.

Employment. In 2007 there were 297 forestry and logging establishments in Wisconsin (USCB 2010b). Of these, 286 were logging, five were timber tract operations, and six were forest nurseries and gathering forest products. Another 26 establishments were considered forestry support. The majority of these forest-related businesses (81%) had one to four employees, and 15% had five to nine employees. Logging alone accounted for 842 employees and an annual payroll of $20.9 million. Forestry support activities employed 70 people with an annual payroll of $1.4 million.

Table 2.18. *Average annual growing stock and sawtimber removals of softwoods and hardwoods in Wisconsin (net), 2003–2008.*

Group	Growing Stock (1,000 cubic feet)	Sawtimber (1,000 board feet)
Softwoods	69,154	210,507
Hardwoods	257,910	738,814
Total	**327,064**	**949,321**

Source: Forest Inventory and Analysis, 2010 (USFS 2010).

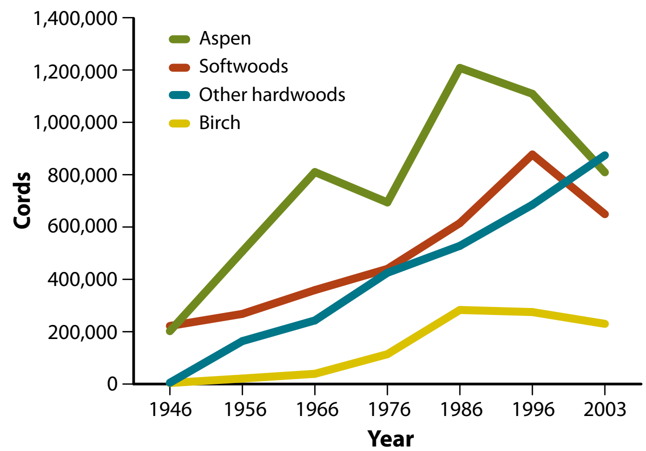


Figure 2.31. *Pulpwood production in Wisconsin by species group at 10-year intervals, 1946–2003. Data from U.S. Forest Service (Reading and Whipple 2007).*

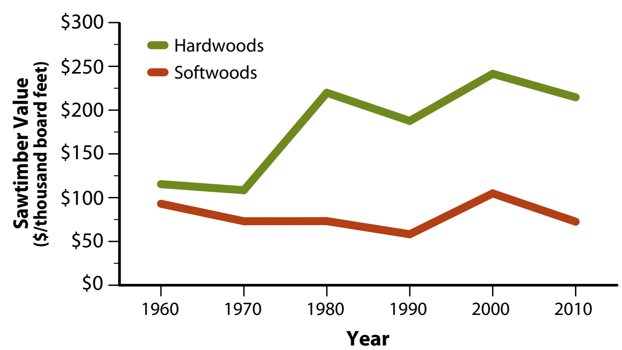


Figure 2.32. *Average (inflation-adjusted) sawtimber value for Wisconsin's hardwood and softwood species. Data from Wisconsin DNR Forest Crop Law and Managed Forest Law stumpage values for severance tax.*

Nontimber Forest Products

Maple sugaring has a long tradition in Wisconsin beginning with American Indian hunter-gatherers. Today Wisconsin is one of the nation's leading maple syrup producers. In 2009 Wisconsin produced 200,000 gallons of maple syrup, contributing $7.3 million to the state economy (NASS 2011). In addition to the maple syrup that is commercially harvested, individuals also tap trees for their own personal consumption as well as localized distribution. This small-scale harvesting also contributes to Wisconsin's economy, although this type of income is often not reported.

Table 2.19. *Average stumpage prices for Wisconsin's sawtimber and pulpwood (not adjusted for inflation).*

	Sawtimber ($ per thousand board feet)						Pulpwood ($ per cord)					
Species	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**
Cedar	10.00	12.00	24.00	21.85	101.25	80.83	1.60	1.60	3.60	4.78	18.38	9.85
Fir	NA	NA	NA	26.38	67.00	74.67	4.60	3.70	4.04	4.27	15.05	15.60
Hemlock	13.00	13.00	22.00	23.31	86.25	98.63	3.70	4.00	6.40	5.86	9.46	11.30
Jack pine	10.00	12.00	27.00	29.62	49.05	72.77	5.00	5.60	12.50	13.42	29.87	28.69
Red pine	21.00	21.00	47.00	57.62	116.09	97.77	4.60	4.40	9.58	12.72	31.38	31.54
White pine	23.00	21.00	50.20	56.85	132.15	16.46	3.30	2.70	6.38	8.45	20.94	19.08
Spruce	14.00	13.00	27.00	28.77	84.00	89.15	7.00	7.00	6.64	7.80	20.26	28.54
Tamarack	10.00	12.00	24.00	34.62	26.62	50.00	2.90	3.20	4.10	5.13	17.31	17.54
Aspen	6.00	9.00	21.60	22.38	49.57	62.00	1.80	2.20	3.80	5.16	20.88	18.92
Ash	12.00	12.00	29.00	83.31	151.17	117.85	NA	NA	NA	NA	NA	20.75
Basswood	24.00	30.00	45.60	76.23	152.14	128.08	NA	NA	NA	NA	8.51	6.77
White birch	14.00	32.00	38.00	47.38	125.48	110.00	1.80	1.60	2.52	5.40	16.49	18.08
Yellow birch	38.00	56.00	58.00	62.38	186.80	182.00	NA	NA	NA	5.40	16.49	18.08
Elm	10.00	16.00	37.20	61.85	87.03	62.31	NA	NA	NA	NA	NA	20.75
Sugar maple	24.00	30.00	61.40	99.62	295.84	367.15	NA	NA	NA	NA	NA	20.75
Other maple	12.00	13.00	40.00	70.85	145.14	158.00	NA	NA	NA	NA	NA	20.75
Red oak	16.00	16.00	76.00	130.15	345.70	268.38	NA	NA	2.58	6.28	11.69	15.15
White oak	16.00	16.00	50.00	104.00	180.67	155.23	NA	NA	2.58	6.28	11.69	15.15
Other oak	10.00	12.00	29.00	60.77	126.87	142.46	1.20	1.20	2.58	6.28	11.69	15.15
Other hardwood	6.00	9.00	36.00	64.69	149.49	132.00	1.60	1.00	2.74	5.07	11.82	20.75
Black walnut	NA	NA	558.00	578.46	482.65	904.44	NA	NA	NA	NA	NA	20.75
Fuelwood	NA	NA	NA	NA	NA	NA	0.50	0.50	2.74	5.07	8.68	8.77

Source: Wisconsin DNR Forest Crop Law stumpage values for severance tax.
NA – Information for this species is not available.

In 2007, 950,000 Christmas trees were harvested for sale in Wisconsin, over 5% of the total national production (USCB 2010a). Numerous other forest products provide social and economic benefits to Wisconsin residents. On private and public land, people collect goods such as evergreen boughs and cones, mushrooms, nuts, berries, moss, and plants.

Water (Ground and Surface)

Wisconsin gets its water supply from two sources: surface water and groundwater. Surface water sources include rivers, lakes, streams, and reservoirs while groundwater sources include wells and springs. There are almost 84,000 miles of rivers and streams (including intermittent streams), 1.2 million acres of lakes, and 1,000 miles of Great Lakes shoreline in Wisconsin (Kenny et al. 2009).

In 2005 the total population of Wisconsin was 5.5 million. Of this total, 3.9 million (70%) received their water from public water supply systems (Kenny et al. 2009). Fifty-seven percent of the publicly supplied population (2.2 million people) received their water from groundwater sources while the other 43% (1.7 million people) were supplied by surface water. The remainder of Wisconsin's population in 2005, totaling 1.6 million people, received their water from self-supplied sources such as water wells.

Numerous entities put demands on the state's water supply, including withdrawals made by commercial, domestic, industrial, thermoelectric power, mining, agricultural, hydroelectric, and wastewater treatment facilities and interests. Each day, 8.6 billion gallons of groundwater and surface water are withdrawn in Wisconsin (see Table 2.20). Almost 89% of the withdrawals are from surface water, with thermoelectric power facilities using the greatest amount (6.9 billion gallons per day). Water used for industrial purposes comes primarily from surface water as well (400 million gallons per day) Of the 975 million gallons of groundwater that are withdrawn each day, 387 million are used for irrigation (40%), and 305 million (31%) are from the public supply.

Table 2.20. *Water use in Wisconsin, 2005.*

	Withdrawals (million gallons per day)		
Water User	**Groundwater**	**Surface water**	**Total**
Public	305	247	552
Domestic	87	0	87
Industrial	71	400	471
Thermo-electric	3	6,895	6,898
Livestock	66	7	73
Irrigation	387	15	402
Aquaculture	39	43	82
Mining	18	15	33
Total	**975**	**7,622**	**8,597**

Source: Kenny et al. (2009).

Socioeconomic Overview

The Land

Sixteen percent of the land in Wisconsin is owned by various public agencies (WDNR 2006). Approximately 45% of the public land is managed by the counties, 30% is managed by the federal government, 24% is managed by the Wisconsin DNR, and 1% is managed by local governments. The majority of the public land is in the northern half of the state. More than one-third of the land in Ashland, Bayfield, Douglas, Florence, Forest, Iron, Price, Sawyer, and Vilas counties is in public ownership. Wisconsin's American Indian tribes own about 1% of Wisconsin land, the majority of this being Menominee County, all of which is the Menominee Indian Reservation.

Approximately 16.7 million of Wisconsin's 35 million acres of land are forested (USFS 2010). Private landowners own the majority of this land (62%). Twenty-nine percent of the forestland is public, of which the majority (15%) is managed by counties and municipalities. The federal government owns about 10%, and the state owns 5%. Seven percent of the forests are owned directly by the forest industry, and 2% are owned by American Indian tribes.

Demography

According to the U.S. Census Bureau, Wisconsin's population was 5.36 million in 2000 and had grown to 5.69 million by 2010, about 1.8% of the total U.S. population (USCB 2011c). Though population growth and urbanization are occurring in Wisconsin, the state retains much of it rural character, with over 27% of its population classified as rural (USDA ERS 2010d). Milwaukee County is Wisconsin's most populous county, with 947,735 people in 2010 (USCB 2011c). Of the state's 72 counties, in 2010 only 15 had over 100,000 people; 44 counties had fewer than 50,000 people.

Wisconsin's population density in 2010 was 104.7 persons per square mile, higher than the national average of 87.3 persons per square mile (USCB 2011c). Wisconsin's northern regions are much more sparsely populated than the more urban southern portion of the state, especially the southeast.

The largest population center in the state is the city of Milwaukee, which ranks 28th among U.S. cities with a population of 594,833 in 2010 (USCB 2011b). Milwaukee suffered a 4% population decrease, primarily to its suburbs, between 2000 and 2010 (USCB 2011c). The second largest city is the state capital, Madison, where population is rapidly increasing—from 208,054 in 2000 to 233,209 in 2010. Other large regional population centers are Green Bay (population 104,057) in the east, Kenosha (99,218) and Racine (78,860) in the southeast, Appleton (72,623) and Oshkosh (66,083) in the Fox River valley, Eau Claire (65,883) in the west, and Wausau (39,106) in the north.

Wisconsin's age distribution is quite similar to the U.S., with a statewide median age of 38.5 years old in 2010 compared to 37.2 nationwide (USCB 2011a). In 2010, 13.7% of Wisconsin's population was aged 65 and older, slightly higher than the national figure of 13.0%. Wisconsin is similarly representative of the U.S. for the age groups of under 18 (23.6% for Wisconsin versus 24.0% for the U.S.) and between 25 and 49 (33.1% for Wisconsin versus 34% for the U.S.)

Wisconsin tends to have a more aging population in its north than in the south. While 15 northern counties have greater than one-fifth of their population aged 65 and older, some southern and western counties have just over 10% of their population aged 65 and older, in part associated with their higher level of urban influence and the accompanying economic opportunities that draw a younger workforce to those regions (USCB 2011a).

Population growth rates tend to be higher in regions with considerable suburban character, as Wisconsin's population flows outward from urban centers. Statewide, population grew by 6% from 2000 to 2010 (USCB 2011c). St. Croix County, influenced heavily by the expansion of the Twin Cities metropolitan area, has experienced especially sharp population growth (33.6%) from 2000 to 2010. Rural northern counties have experienced the least population growth from 2000 to 2010. Nineteen Wisconsin counties lost population during that same period, with the greatest loss occurring in Iron (13.8% loss) and Florence (13.1% loss) counties.

In 2009 Wisconsin had a slightly higher percentage of high school graduates (from the 25 and older age range) than the U.S. (89% versus 84.6%) but slightly fewer college graduates from the same age range (25.5% compared to 27.5%) (USCB 2011c).

The racial makeup of Wisconsin is more homogenous than the United States as a whole, even though the percentage of ethnic groups other than Caucasians has been slowly increasing. In 1960 approximately 97.6% of the state's residents were Caucasian, 1.9% were African American, and 0.4% were American Indian (USCB 1963). In 2010, 86.2% of the state's people were Caucasian compared to 72.4% of the U.S. (USCB 2011c). Wisconsin has relatively low but increasing percentages of African Americans (6.3% for Wisconsin versus 12.6% for the U.S.), Asians (2.3% versus 4.8%), and Hispanics (5.9% versus 16.3%). The percentage of American Indians was almost the same for both the U.S. (0.9%) and Wisconsin (1%) in 2010.

Housing

In 2010, housing density in Wisconsin was 48.5 homes per square mile, compared to 37.3 nationwide (USCB 2011c). Housing density is unevenly distributed across the state. Milwaukee County had by far the highest housing density statewide, at 1,732 homes per square mile. Waukesha County (293 homes per square mile), Kenosha County (255), and Racine County (247) are other southeastern metropolitan counties with housing densities well above the state as a whole. Housing density was lowest in Menominee County at six homes per square mile. Nine other northern counties had housing densities lower than 10 homes per square mile in 2010.

Housing growth from 2000 to 2010 was at 13.1%, with nuanced factors affecting which regions experience the most growth (USCB 2011c). Sheboygan County had by far the highest housing growth rate from 2000 to 2010, at 40%, followed by Calumet County with 25% housing growth. The lowest levels of housing growth for the same period occurred in rural Crawford County (3.8% housing growth) in the southeast, rural Iron County (5.1%) in the north, and Milwaukee County (4.5%). Most housing development driven by the Milwaukee metropolitan area has occurred at its geographical fringes, much as occurred in west central Wisconsin counties relative to the Twin Cities metropolitan area.

Seasonal housing is a significant portion of housing in Wisconsin, compared to the national figure of about 3.1% seasonal housing in 2000. Seasonal housing was 7.4% of Wisconsin's housing units in 2010 but is highly variable throughout the state (USCB 2011c). Prevalence of seasonal housing is highly correlated to tourism and higher property values, which can be important economic drivers, especially for rural local economies with few other strong economic sectors. The percentage of seasonal housing is generally much lower in more urban counties than in rural counties, especially in the north where forests and lakes are principle attractants to nonresident housing. In 2000, only Vilas County (56.7% seasonal housing) had the majority of its homes classified as seasonal (USCB 2011a). By 2010, Florence (54.2%), Forest (52.7%), Burnett (51.2%), and Sawyer (50.6%) counties had joined Vilas County with more than half of their housing seasonal. Nine other Wisconsin counties had seasonal housing comprising more than one-third of all housing units.

Economy

Per capita income is generally used as a proxy for a region's overall standard of living and is highly correlated with urban influence. Wisconsin's average per capita income statewide from 2005–2009, in 2009 dollars, was $26,447 compared to $27,041 in the United States (USCB 2011c). Both located on the perimeter of the Milwaukee metropolitan area, Ozaukee ($39,441 per capita income) and Waukesha ($36,553) counties had by far the highest per capita incomes in the state during this period, followed by Dane County ($31,846). In contrast, Menominee County had the state's lowest per capita income at $13,575. Only 14 Wisconsin counties had per capita incomes above the statewide average, indicating a concentration of higher paying jobs in urbanized counties.

Median household income in Wisconsin in 2009 was $49,994, compared to $50,221 in the United States (USCB 2011c). Median household income was highest in Ozaukee ($73,830) and Waukesha ($72,982) counties, followed by St. Croix County ($65,679). Twenty-three Wisconsin counties had median household incomes exceeding the statewide figure. Menominee ($30,648) and Iron ($34,201) counties had the lowest median household incomes in the state.

The U.S. Bureau of Labor Statistics estimated that Wisconsin's statewide average unemployment rate in 2010 was 8.3%, lower than the nationwide figure of 10.8% (USDL BLS 2010b). Unemployment was lowest in Dane County (5.6%) followed by La Crosse County (6.3%). Unemployment was particularly high in Menominee County (15.5%), while twenty other Wisconsin counties had greater than 10% average unemployment in 2010. Whereas most Wisconsin counties with relatively high unemployment are rural and northern, the state's most urban counties are among those counties with poor unemployment figures; Kenosha County (10.8%) and Racine County (10.0%) were among Wisconsin counties with the highest unemployment rates (USDL BLS 2010a).

Wisconsin's overall poverty rate was estimated at 12.4% in 2009 (USCB 2001C) but was highly variable throughout the state. Menominee County has by far the state's highest poverty rate, at 31.7% in 2009. Milwaukee County had the second-highest poverty rate (20.6%), despite high earnings per job figures. This discrepancy points to both abundant high-paying jobs driving up the average wage figures, alongside large populations in urban areas without economic opportunities. Other counties with high poverty rates include rural, agricultural Vernon County in southwestern Wisconsin and counties concentrated in the north and especially the northwest. Poverty rates were lowest in Waukesha County (4.9%) and Ozaukee County (5.1%), where many workers in high-paying Milwaukee County jobs reside.

Median housing values statewide in 2009 were $166,100 per owner-occupied unit, compared to $185,400 nationwide (USCB 2011c). Housing values were highest in Waukesha ($256,400 per owner occupied unit), followed by Ozaukee ($249,400), Dane ($226,900), St. Croix ($224,500), and Washington ($224,200) counties. Housing values were lowest in Menominee County ($74,300), followed by Ashland County ($100,300) and Iron County ($102,800) and were similarly low in other northern counties and in agricultural counties.

Data in Table 2.21 reflect economic numbers that hint at the onset of a recession for both the U.S. and Wisconsin in 2008. However, the relationship between the nation as a whole and Wisconsin's economy are the main focus here. Overall, measures of earnings are dropping but slightly less so in Wisconsin than in the nation as a whole. However, Wisconsin's poverty rate has recently been climbing faster than the U.S. Overall unemployment remains lower in Wisconsin than in the nation as a whole.

Generally, Wisconsin's 25 urban counties lag slightly behind all U.S. urban counties in terms of earnings but compare favorably in terms of poverty rate and unemployment rate (Table 2.21). Wisconsin's 47 rural counties compare favorably to the U.S. in per capita income, poverty rate, and unemployment rate but are trending negatively at a slightly higher rate than the nation's rural counties.

Important Economic Sectors

There were nearly 3.56 million full time and part-time jobs in Wisconsin in 2006. Figure 2.33 shows the service sector

Table 2.21. *Economic indicators for Wisconsin and the United States, 2008.*

Category	United States	Percent change	Wisconsin	Percent change
Total				
Per capita income[a]	$40,166	-1.8	$37,770	-1.7
Earnings per job	$50,259	-2.7	$43,852	-2.4
Poverty rate[b]	13.2%	8.1	10.5%	20.7
Unemployment rate[c]	5.8%		4.8%	
Urban counties[d]				
Per capita income	$41,953	-2.1	$39,685	-1.8
Earnings per job	$52,699	-2.9	$43,852	-2.4
Poverty rate	12.9%	8.4	10.4%	19.5
Unemployment rate	5.8%		4.6%	
Rural counties[d]				
Per capita income	$31,108	0.3	$32,611	-1.2
Earnings per job	$36,180	-1.1	$35,128	-2.8
Poverty rate	15.1%	2.0	10.7%	24.4
Unemployment rate	5.6%		5.2%	

Source: Economic Research Service, May 7, 2010 State Facts Sheet: Wisconsin (USDA Economic Research Service 2010d).

[a]Income and earnings figures are 2008 with percentage of change from 2007 in 2008 dollars.
[b]Poverty rate figure is 2008 (latest model-based estimates) with percentage of change from 1999 to 2008.
[c]Unemployment rate figure is 2008.
[d]Urban and rural (metro and nonmetro) definitions are based on the Office of Management and Budget (OMB) June 2003 classification.

divided into its relevant subsectors. Manufacturing had the greatest portion of Wisconsin employment, with 14.1% of all jobs in the state, followed by government employment (12.1%), retail trade (11.2%), and health care and social assistance (11.2%). The service sector as a whole employs the most people in Wisconsin. Within the service sector, health care and social assistance included the highest number of Wisconsin jobs.

Urban Influence

The U.S. Department of Agriculture Economic Research Service divides counties into 12 groups on a continuum of urban influence, with 1 representing large metropolitan areas, 2 representing smaller metropolitan areas, and the remaining classes from 3 to 12 representing nonmetropolitan counties increasingly less populated and isolated from urban influence (USDA ERS 2010c). The concept of urban influence assumes that population size, urbanization, and access to larger adjacent economies are crucial elements in evaluating potential of local economies. Wisconsin has counties at all levels of the urban influence spectrum, indicating a diverse state demographic and economic structure. Wisconsin's distribution of urban influence among its counties is relatively similar to that of the nation as a whole.

Seven Wisconsin counties are classified as class 1 (large metropolitan area of at least one million residents), including counties around and containing the Milwaukee metropolitan area, Kenosha County in southeastern Wisconsin, and Pierce and St. Croix counties in northwestern Wisconsin on the edge of the Twin Cities metropolitan region (USDA ERS 2010c). Eighteen Wisconsin counties are classified as class 2 (small metropolitan area of less than one million residents). Of Wisconsin's nonmetropolitan counties, only three (Dodge, Jefferson, and Walworth counties) are classified as class 3 (micropolitan area adjacent to large metropolitan area) urban influence counties. Only two Wisconsin counties (Burnett and Polk counties) are classified as class 4 (noncore area adjacent to large metropolitan area), under the influence of the Twin Cities metropolitan area. Nine counties are classified as class 5 (micropolitan area adjacent to small metropolitan area), such as Dunn County, which contains the small city of Menominee and is adjacent to Eau Claire County and near the city of Eau Claire. Sixteen Wisconsin counties are classified as class 6 (noncore area adjacent to small metropolitan area and contains a town of at least 2,500 residents). Seven counties are classified as class 7 (noncore area adjacent to small metropolitan area and does not contain a town of at least 2,500 residents). Florence County is Wisconsin's only county classified as class 8 (micropolitan area not adjacent to a metropolitan area). Three Wisconsin counties (Crawford, Juneau, and Oneida) are classified as class 9 (noncore area adjacent to micropolitan area and contains a town of at least 2,500 residents). Forest County is the only Wisconsin County classified as class 10 (noncore area adjacent to micropolitan area and does not contain a town of at least 2,500 residents). Ashland and Price

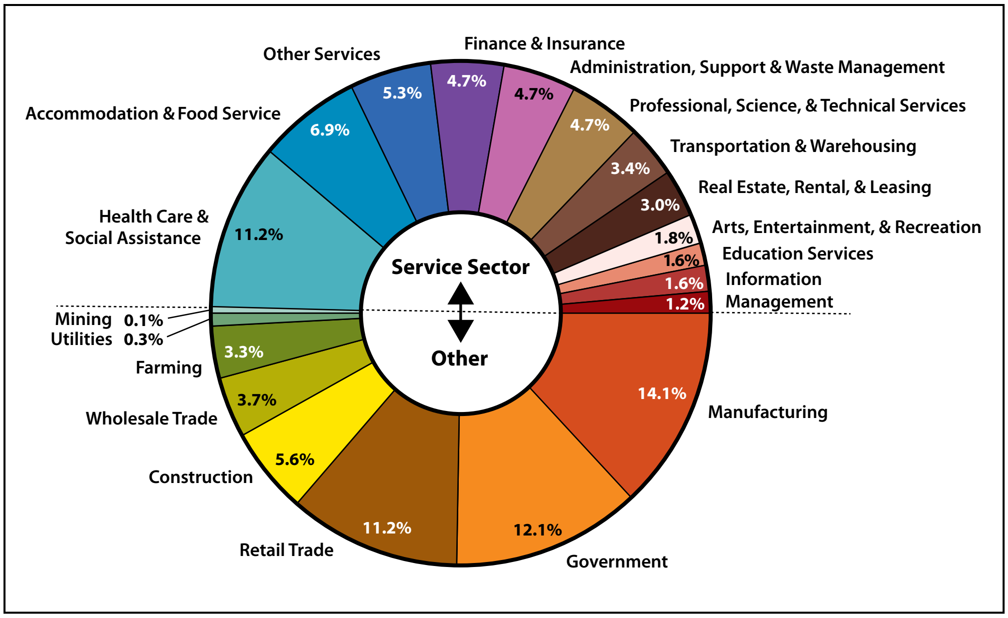


Figure 2.33. *Percentage of jobs in Wisconsin according to employment sector, 2006. See Glossary, Part B, in Part 3, "Supporting Materials," for definitions of the economic sectors.*

counties are classified as class 11 counties (noncore area not adjacent to metropolitan or micropolitan area and contains a town of at least 2,500 residents). Iron, Sawyer, and Vilas counties are classified as class 12 (noncore area not adjacent to metropolitan or micropolitan area and does not contain a town of at least 2,500 residents) with the least benefits from urban influence.

Differences among Nonmetropolitan Counties

On the subject of economic growth in rural areas, the U.S. Department of Agriculture Economic Research Service developed a typology of nonmetropolitan (rural) counties. This classification system places rural counties into one of six categories of economic specialization: farming, mining, manufacturing, government, services, and nonspecialized.

Forty-seven of Wisconsin's 72 counties are considered nonmetropolitan (USDA ERS 2010b). Based on economic type, 36 counties are manufacturing dependent, 26 counties are nonspecialized, five are service dependent, three are government dependent, two are farming dependent (six were farming dependent in 2000, indicating the decreasing influence of agriculture on local economies), and no counties are mining dependent. Of the economic groups, the manufacturing-dependent counties had the greatest total population, highest average population per county and lowest poverty rate in 2000. Those counties also tended to have higher per capita income, greater total number of jobs, and the most earnings per job.

The U.S. Department of Agriculture Economic Research Service classifies counties according to seven "policy types" deemed especially relevant to rural development policy (USDA ERS 2010b). Five of these policy type classifications describe stress indicators for local economies: housing stress, low education, low employment, persistent poverty, and population loss. Two of the policy type classifications, nonmetropolitan recreation counties and retirement destination counties, present both challenges and opportunities for local economies.

Wisconsin has 21 nonmetropolitan recreational counties (USDA ERS 2010b). Nonmetropolitan recreation counties are rural counties classified using a combination of factors, including share of employment or share of earnings in recreation-related industries in 1999, share of seasonal or occasional use housing units in 2000, and per capita receipts from motels and hotels in 1997, indicating economic dependence especially upon an influx of tourism and recreational dollars.

Wisconsin has 14 retirement destination counties, those counties in which the number of residents 60 and older grew by 15% or more between 1990 and 2000 due to immigration shaped by an influx of an aging population with particular needs for health care and services specific to that population (USDA ERS 2010b). Nearly all retirement destination counties are also nonmetropolitan recreation counties, with the only two exceptions being Waupaca County and Polk County. These county types tend to be concentrated in northern Wisconsin.

Only two Wisconsin counties are classified with any of the stress indicator policy types (USDA ERS 2010b). Milwaukee County, containing the urban core of the city of Milwaukee, is classified as both a housing stress county and a population loss county. Menominee County, home of the Menominee and Stockbridge Muncie Indian Reservations, is classified as both a housing stress county and a low employment county.

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